CUTLER POWER PLANT SEAGRASS MONITORING PROGRAM – FALL 2011

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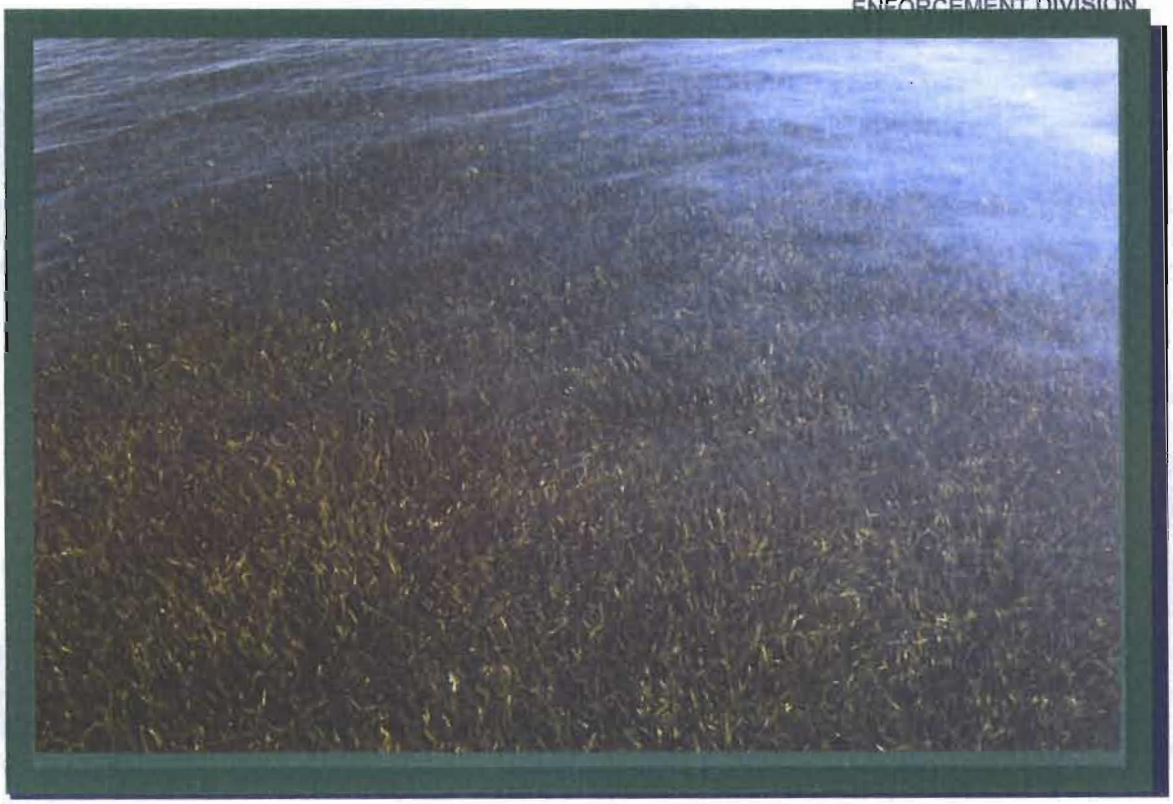

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November 2011

ASSESSMENT OF SEAGRASSES
CUTLER PLANT, OCTOBER 2011

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EXECUTIVE SUMMARY

On January 18, 2006, the Florida Department of Environmental Protection issued Florida Power & Light Company (FPL) a 5-year Industrial Wastewater Facility Permit (FL0001481) for operation of the Cutler Power Plant. The Cutler Plant, when operational discharges warm thermal effluents from its once-through cooling water system into a shallow embayment in Biscayne Bay. To minimize thermal impacts to seagrasses, auxiliary pumps are used to supplement ambient water mixing at the point of discharge. As a condition of its permit, FPL is required to perform semiannual thermal and seagrass monitoring within the Cutler embayment to assess the effectiveness of this measure. The results of the most recent survey, conducted in October 2011, are presented in this report.

Overall seagrass conditions within the Cutler embayment during Fall 2011 were very similar to those observed during the previous spring survey. Within the inner basin, shoal grass was found to be uniform and very dense. Although turtle grass remained widely scattered throughout the inner basin, its distribution had expanded landward since the previous survey. This species had only rarely been observed within shoreward portions of the inner basin prior to 2008. Its persistent high coverage in this area during the fall of 2011 is indicative of improved water quality conditions during recent years, the apparent result of limited plant operations. Farther offshore (transition zone and outer basin), conditions within the seagrass community were essentially unchanged from the previous survey.

Thermal data collected during the summer of 2011 indicate that water temperatures within the Cutler embayment, although highly variable, were well below average on both a daily and seasonal basis, and exposure to potentially stressful water temperatures was very low. The improvements noted above are likely the culmination of six consecutive years of low water temperatures.

Field monitoring performed since 1991 provides clear evidence that seagrasses have responded favorably to modified plant operation. An overall increase in the coverage, density, and biomass of seagrasses over the period of monitoring, as well as an overall improvement in their relative condition, has been documented since supplemental pumping was initiated. A gradual shoreward expansion of turtle grass, the species

characteristic of climax seagrass communities in south Florida, supports model predictions of improved thermal conditions within the Cutler embayment resulting from modified plant operation.

The positive trends in seagrass community characteristics documented within the Cutler embayment have been gradual but persistent. Seasonal changes sometimes occur as grasses respond to alternating periods of elevated summer water temperatures and more moderate winter temperatures. Occasionally, the improvements noted above have been temporarily reversed by protracted periods of high summer water temperatures. It appears that when these high temperatures are accompanied by unusually low salinities, as presumably occurred during the summers of 1995 and 2004, the setbacks are particularly noticeable. However, upon return of more favorable water quality patterns, seagrass conditions are capable of responding favorably. A noticeable improvement in seagrass community characteristics, particularly an increase in turtle grass coverage within inner portions of the embayment, has been documented during recent years. This corresponds to a period of limited plant operations.

INTRODUCTION

The Cutler Embayment, a shallow cove on the western shore of Biscayne Bay (Figure 1), receives thermal discharges from Units 5 and 6 of Florida Power & Light Company's (FPL's) 232 MW Cutler Power Plant (PCU). In 1992, in an effort to minimize impacts to seagrasses from PCU's once-through cooling water discharges, FPL installed auxiliary pumps to supplement ambient water mixing at the point of discharge. A simplistic model predicted that this modification to plant operations would improve overall thermal conditions within the embayment and would thus promote a healthier seagrass community.

Preliminary seagrass monitoring within the Cutler embayment began in October 1991. Supplemental pumping was initiated in June 1992 and a formal thermal and seagrass monitoring program, reviewed and approved by the Florida Department of Environmental Protection (FDEP), was implemented concurrently. On January 18, 2006, FDEP issued FPL a 5-year Industrial Wastewater Facility Permit (FL0001481) for continued operation of the Cutler Plant. The permit requires continued semiannual (spring and fall) thermal and seagrass monitoring, as described in FPL's July 16, 1992 Cutler Monitoring Plan. This report presents results of fall monitoring performed by Ecological Associates, Inc. (EAI) during October 2011.

METHODS

Seagrass Monitoring

Fall 2011 monitoring was performed by EAI biologists on October 3, 2011. Seagrass composition, cover, density and relative condition were assessed along six transects radiating 2400 feet (732 m) seaward from the mouth of PCU's discharge canal (MODC; Figure 2). At 100-foot (30.5-m) intervals along each transect or whenever a substantial change in seagrass coverage or composition was observed, a m^2 PVC frame sub-divided into sixteen (16) 10X10 inch (25X25 cm) squares was randomly dropped to the bottom three times. Coverage was determined by counting the number of squares occupied by each species and averaging the percentage of squares occupied for all three drops. Density in each frame was qualitatively determined for all species combined using the following categories: dense (blades thick throughout the frame, nearly obscuring the bottom), moderate (areas of open bottom visible between patches of grass), and sparse (bottom clearly visible between widely scattered blades of grass). Additionally, each species present was assessed for relative condition.

Thermal Monitoring

Water temperatures were measured using HOBO® Water Temp Pro.v2 data loggers. These instruments are specifically designed to accurately and remotely record temperatures during extended immersions in water. All data loggers utilized in this study were factory-calibrated against a National Institute of Standards and Technology (NIST) traceable reference and are certified accurate to within 0.4°F (0.2°C).

On April 13, 2011, EAI personnel installed recording data loggers at each of three stations located 1000 (305 m), 1500 (457 m), and 2000 feet (610 m) from the MODC on Transect 1 (Figure 2). These locations correspond to those monitored previously. Because of prior instrument loss and failure, two instruments were installed per station to provide redundancy in the event one instrument was lost or malfunctioned. The buoyant data loggers were attached to anchor posts and floated in the water column 6-12 inches (15-30 cm) above the bottom. They were pre-programmed to record measurements once each hour throughout the summer. The units were retrieved on October 3, 2011.

Base data from each thermograph was downloaded onto a personal computer and hourly temperature readings from each of the two data loggers at each location were compared to ensure data reliability. Average differences between paired hourly readings at the three stations were found to be minimal (0.02-0.32°F; 0.01-0.18°C), and thus data from only one of the two instruments at each station were randomly chosen for analysis.

Prior to analysis, data were truncated to include only those days with a complete 24-hour temperature record (April 14 through October 2). The base data were then used to calculate mean daily and mean hourly water temperatures. As presented in this report, mean daily water temperatures are the average of the 24 hourly values recorded each day.

Mean hourly temperatures are the average of specific hourly readings calculated each day over the period of record. Data collected from June through August were used for assessing inter-annual variations in temperature patterns. This time frame has historically encompassed the period of maxima seasonal water temperatures.

Biomass Monitoring

To provide a quantitative index of seagrass density, above-ground biomass was determined 300 (91 m), 600 (183 m), 1200 (366 m), 1800 (549 m), and 2400 feet (732 m) seaward of the MODC along Transect 1 (Figure 2). Within a 15-foot (4.6-m) radius of each of these locations, a 4 square inch (25 cm^2) quadrat was randomly dropped to the bottom three times. Seagrass blades within each quadrat were clipped at ground level and returned to the lab where they were clipped at ground level and returned to the lab where they were processed to remove epiphytes and epibiota. Mean biomass of live blades was determined for each species after oven drying the samples to constant weight at 230°F (110°C).

RESULTS AND DISCUSSION

Seagrass Monitoring

Transect data (Tables 1-6) were used to generate a gross-scale map depicting seagrass zonations within the Cutler embayment during October 2011 (Figure 3). Only areas visually surveyed are included in the map. Contours extended beyond the perimeter of the survey area may not be reliable.

Thermal effluents leave the Cutler Plant through a dredged discharge canal (Figure 2). At the MODC, the dredged canal transitions into a shallower channel that steadily decreases in depth until it eventually grades with the natural bottom about 350 feet (107 m) from shore. Scouring caused by relatively strong currents within the channel has largely removed the sediments necessary to establish and support macrophytic roots and rhizomes; this area has been devoid of seagrasses since the current monitoring program began in 1991. During the October 2011 survey, the narrow, elliptical shaped area encompassing the dredged discharge channel was once again devoid of seagrasses (Figure 3).

Shoal grass (*Halodule wrightii*) was present in dense beds almost immediately outside of the discharge channel. Shoal grass is the most eurythermal species of seagrass (i.e. capable of tolerating the widest range of temperatures; Phillips, 1960), and thus, it has historically dominated the areas of the embayment closest to the MODC. Throughout most of the landward portion of the embayment (inner basin), this species was ubiquitous. With the exception of the discharge channel and rocky areas close to shore, coverage was 100% at nearly all of the survey points (Tables 1-6). During the Fall 2011 survey, this uniform and dense carpet of shoal grass extended outward from the MODC a distance of

250 to 550 feet (76 to 168 m).

Farther away from the MODC, shoal grass densities within the inner basin exhibited greater variability, sometimes over relatively small spatial scales. However, average densities for the three replicates combined at each station were consistently classified as either moderate or dense (Tables 1-6).

Although its coverage was initially sporadic, turtle grass (*Thalassia testudinum*) began occurring occasionally in quadrats about 250 to 550 feet (76 to 168 m) seaward of the MODC. Prior to 2008, this species was rarely observed within 1,000 feet (305 m) of the MODC anywhere within the embayment. However beginning in 2008, *Thallasia* began expanding in coverage and rapidly colonized areas from which it was previously absent. This expansion continued gradually through the fall of 2009 and 2010, at which time it was relatively widespread throughout the inner basin. During the Fall 2011 survey, turtle grass was once again widely scattered throughout the inner basin.

Along each transect, the approximate location where turtle grass becomes persistent within survey quadrats functionally defines the landward edge of a transition zone where shoal grass and turtle grass distributions blend but neither exhibits dominance. During the Fall 2011 survey, turtle grass generally became persistent between 750 (229 m) and 1,250 feet (381 m) from the MODC (Figure 3; Tables 1-6). During the fall of 2011, seagrasses within the transition zone occurred in moderate to dense assemblages, and coverage was relatively high.

Seaward of the transition zone, between 1,250 to 1,550 feet (381 to 472 m) from the MODC (outer basin), shoal grass was abruptly displaced by turtle grass. The only exception to this trend occurred within the southwest portion of the embayment (Transect 4), where coverage of both turtle grass and shoal grass was generally sparse. Seagrasses disappeared from this portion of the embayment between the Fall 2003 and Spring 2004 surveys, and they have yet to fully recover.

Elsewhere within the outer basin, *Thalassia* formed nearly continuous dense beds, although irregular patches of disturbed bottom were occasionally present. These patches, also documented during most previous surveys, were of varying dimensions ranging from less than one to several meters in diameter. *Halodule* had recolonized many of these areas. Some patches of grass appeared to have been "clipped" immediately above the substrate, while others were characteristic of a "blow-out" (i.e. bare areas with an eroding edge that forms a vertical wall of overhanging seagrass roots and rhizomes). The turtle grass that surrounded the open patches generally appeared robust, indicating that mechanical disturbances (e.g., feeding scars, vessel groundings, storms, etc.) rather than thermal impacts were probably responsible for their formation.

Coverage, density and overall appearance of grasses throughout the embayment were generally good. Water clarity during October 2011 monitoring was fair, as a result of breezy winds and choppy wave conditions.

Thermal Monitoring

The purpose of the thermograph data is to provide a time-integrated picture of prevailing summer water temperatures at varying distances from the MODC. Locations were chosen to represent a gradient of thermal conditions and seagrass zonations.

As in previous years, there was considerable variability at each station in average daily water temperatures over the period of record (Figure 4). These day-to-day fluctuations were shown previously to correspond to changes in plant operating conditions, which in turn are related to energy consumption within the FPL system. However, short-term fluctuations can also result from changes in prevailing weather conditions, as is evident in the 2011 data. The Cutler Plant did not operate during any portion of the summer, and thus day-to-day fluctuations in water temperatures are solely related to natural environmental variables, such as air temperatures, cloud cover, rainfall, and water depth.

The lowest average daily temperature (78.8°F; 26.0°C) recorded over the period of record occurred on April 23, 2011, and the highest (93.0°F; 33.9°C) on July 13, 2011 (Figure 4). Notwithstanding short-term daily fluctuations, temperatures began a steady increase throughout mid-April before approximating maximum conditions in mid-July. From that point, water temperatures gradually declined through the end of the monitoring period.

During the summer of 2011, average daily water temperatures fluctuated considerably but were predominantly below average (Figure 5). Water temperatures at the 1500-foot station were representative of conditions throughout the embayment. Temperatures at that station approximated average conditions during the beginning and end of the monitoring period, but were typically below average for most of the summer (June to August). Data from this station indicated that the embayment was relatively cool during the summer of 2011, with water temperatures occasionally falling below historical minimum values for brief periods. Only once in mid-September did average daily water temperatures at this station approach historical maximum values.

Due to differences in the amount of water temperature data collected each year, data are typically truncated to yield comparable periods of record. The truncated data set runs from June through August and has consistently encompassed the period of highest mean daily water temperatures for the year (Figure 4). Because this time frame is thought to fairly characterize "summer" conditions, it is used for assessing inter-annual variability.

During the summer of 2011, highest mean hourly water temperatures at all stations generally occurred in the late afternoon around 5:00 PM (Figure 6). Coolest water temperatures were recorded about 8:00 AM. Although the absolute values for mean hourly temperatures have varied considerably over the period of monitoring, the overall daily temporal patterns have been very consistent; warmest temperatures occur in the late afternoon and coolest temperatures are recorded shortly after daybreak. Differences between the three stations were most apparent during afternoon hours.

From graphic comparisons, it is apparent that hourly mean water temperatures 1000 feet (305 m) from the MODC during 2011 were about 1.8 to 2.7°F (1.0°C to 1.5°C) below historical averages and generally approximated the historical minima (Figure 7). Hourly mean water temperatures at the 1500- and 2000-foot stations were also about 1.8°F (1.0°C) below average (Figures 8 and 9).

A simplistic model of thermal discharges from the Cutler Power Plant shows that when PCU is operational, summer water temperatures decrease steadily in a seaward direction away from the MODC. Statistical tests performed on complete water temperature data sets collected during previous years of monitoring when the plant has been operational have been consistent with this model. Temperatures at the 1000-foot station have typically been significantly warmer than those 2000 feet from the MODC, while temperatures 1500 feet from the MODC have sometimes differed significantly from one or both of the other two stations.

Over the entire period of record during 2011 (April 14 through October 2), mean daily water temperatures averaged 86.0°F (30.0°C) at the 1000-foot station, 85.8°F (29.9°C) at the 1500-foot station, and 85.5°F (29.7°C) at the 2000-foot station. An Analysis of Variance (ANOVA) applied to these data indicated that none of the differences among stations were statistically significant ($F_{2, 513} = 0.114993$, $p > 0.05$). Thus, water temperatures were not only below their historical averages, they were also relatively uniform throughout the embayment, again a reflection of the lack of plant operation during 2011.

The most relevant aspect of thermal patterns within the Cutler embayment with respect to seagrasses is the frequency and duration of exposure to high temperatures. The literature suggests that sustained temperatures between 91.4°F and 95.0°F (33.0°C and 35.0°C) are stressful to turtle grass, the species characteristic of climax seagrass communities in Biscayne Bay (Zieman, 1982). Temperatures above 95.0°F may kill the blades, although brief, periodic exposure to temperatures as high as 104.0°F (40.0°C) probably does not affect the root system, which is protected by a layer of insulative sediments. Shoal grass is much more eurythermal in comparison to turtle grass and can better tolerate periodic exposure to high temperatures.

During what is typically the warmest part of the summer (June through August), daily water temperatures 1000, 1500, and 2000 feet from the MODC averaged 87.3°F (30.7°C), 87.1°F (30.6°C) and 86.5°F (30.3°C), respectively (Table 7). These temperatures ranged from 2.3°F to 3.1°F (1.3°C to 1.7°C) below historical averages. The highest hourly temperature recorded during 2011 (96.6°F; 35.9°C) occurred at the 1000-foot station. Average daily maximum temperatures ranged from 90.1°F (32.3°C) at the 1000-foot station to 88.9°F (31.6°C) at the 2000-foot station. These maximum values were about 3.2 to 4.1°F (1.8 to 2.3°C) below average. In fact, average daily water temperatures at each station were equal or close to their respective historical average minima.

With respect to duration of high temperatures, only 0.9, 0.1, and 0.0%, respectively, of all hourly readings taken 1000, 1500, and 2000 feet from the MODC between June and August of 2011 exceeded 95.0°F (Table 8). That equates to an average daily exposure of 0.2, 0.02, and 0 hours, respectively, at the three stations. These periods of exposure were much lower than historical averages at all three monitoring stations, which were 3.8, 2.1, and 1.1 hours per day, respectively. Exposure to temperatures above 95.0°F was similar to the historical minimum set in 2009 at each of the three stations.

Of equal importance to the amount of time grasses are exposed to high temperatures is the amount of relief they receive between periods of exposure. During 2011, 74.6, 77.7, and 81.3%, respectively, of all hourly readings taken between June and August at the 1000-, 1500- and 2000-foot stations were less than 89.6°F (32.0°C; Table 8). That represents about 17.9 to 19.5 hours per day of optimal growing conditions, which exceeds the amount of thermal relief experienced during any of the prior years for which data are available.

In summary, data collected during the summer of 2011 indicate that water temperatures within the Cutler embayment, although typcially variable, were below average on both a daily and seasonal basis. Seagrasses experienced much shorter than average periods of exposure to temperatures above 95°F and, likewise, experienced much longer than average periods of near ambient temperatures (below 89.6°F). Mean daily temperatures were generally below historical averages throughout the summer. A similar pattern was evident on a daily basis, with hourly water temperatures at or below historical minima for the entire day during the warmest portion of the summer (Figures 7, 8, and 9).

Biomass Monitoring

Quantitative biomass measurements demonstrate the healthy condition of grasses within the inner basin (Table 9; Figure 10). Within the inner basin, shoal grass collected at the 300-foot station (3.4 oz/m^2; 106.9 g/m^2) was four times the historical average (0.8 oz/m^2; 25.0 g/m^2) for fall surveys. Only nominal amounts of grass had been collected at this station between 1998 and 2005. Similarly, seagrass biomass at the 600-foot station (3.5 oz/m^2; 108.8 g/m^2) was more than twice as high as the historical fall average (1.5 oz/m^2; 45.7 g/m^2). At the 1200-foot station, seagrass biomass (2.7 oz/m^2; 84.4 g/m^2) was also higher than the corresponding historical average (2.2 oz/m^2; 69.8 g/m^2), although the difference was not as substantial as for the other two stations. Shoal grass biomass at this station has held relatively steady since 2006, whereas biomass at both the 300- and 600-foot stations has risen sharply since 2005 (Figure 10).

Only nominal amounts of turtle grass were collected at the 1200-foot station prior to 2008. However, biomass of this species has been increasing ever since. In 2011, turtle grass biomass at the 1200-foot station (4.2 oz/m^2; 131.9 g/m^2) was at its highest level since monitoring began.

Seaward of 1200 feet, the biomass of shoal grass declined sharply as turtle grass began to dominate the community. *Thalassia* biomass 1800 feet from the MODC was 11.0 oz/m^2

(341.3 g/m^2), which tied the historical maximum value set the previous year. At 2400 feet from the MODC, turtle grass biomass (10.7 oz/m^2; 331.6 g/m^2) was about average (10.0 oz/m^2; 309.5 g/m^2) in comparison with previous fall surveys.

Biomass of shoal grass surrounding the MODC is illustrative of the effects of thermal discharge on the seagrass community. From 1999 to 2005, shoal grass biomass within 300 feet of the MODC was low, presumably as a result of consecutive summers with above average water temperatures (Figure 10). However, in the fall of 2006 a substantial recovery of grasses in the immediate vicinity of the MODC was observed, demonstrating the ability of the grass to recover quickly following a summer of relatively low water temperatures. In 2011, following a fifth consecutive summer of relatively low temperatures, biomass collected within the vicinity of the MODC was well above average.

Intra-seasonal Comparison

Overall, intra-seasonal differences between the Spring 2011 (Figure 11) and Fall 2011 (Figure 3) surveys were modest. Within the inner basin, turtle grass was widespread and coverage remained relatively stable between the two surveys. However, this species was observed closer to the MODC during the fall survey than during the spring survey. This is indicative of a continuing improvement in water quality conditions and a shoreward expansion of turtle grass in the absence of environmental stress. The density, coverage and composition of the seagrass community within the transition zone during the fall of 2011 were nearly identical to the previous spring survey, and conditions elsewhere within the embayment were also very similar.

Assessment of Seagrass Response to Supplemental Pumping

A simplistic model of the Cutler Plant was developed to depict thermal plume dispersion under different discharge temperatures and volumes. This model, verified by actual field data, indicated that for any static operating load, supplemental pumping would substantially reduce water temperatures at any given distance from the MODC. Because the seagrass community within the Cutler embayment is structured primarily by prevailing water temperatures, and because supplemental pumping reduces the area affected by highest summer water temperatures, it follows that modified operation of PCU should promote increased coverage and density of seagrasses throughout the embayment.

Turtle grass is the species characteristic of climax seagrass communities in the subtropics (Zieman, 1982). Therefore, any long-term improvements in the overall condition of Cutler seagrass communities will largely be reflected in changes in the distribution and abundance of this species. To assess such changes, all coverage data collected to date were tabulated and grouped into four zones:

1. Shoreward areas of the inner basin (within 1000 feet of the MODC),

2. Seaward areas of the inner basin (between 1000 and 1500 feet of the MODC),
3. Transition zone (between 1500 and 1800 feet of the MODC), and
4. Climax community (seaward of 1800 feet; 549 m).

Coverage trends for each station are presented in Figures 12 through 17. Transect 1 can be used to demonstrate the general changes in turtle grass abundance that have occurred within the Cutler embayment since monitoring began (Figure 12). Within the climax community (1800-2400 feet), coverage of *Thalassia* has remained high and relatively stable over the entire period of monitoring. However, within what is traditionally referred to as the seaward portion of the transition zone (1500-1750 feet), an obvious trend of increasing coverage is apparent since supplemental pumping was initiated. During the Fall 1992 survey, turtle grass only covered about 30% of the bottom within the transition zone. By October 1995, after just three years of supplemental pumping, it had reached 75%. It remained at or above this level through 2006, and since then has never fallen below 100%. In effect, this zone has now been incorporated into the climax community.

Although turtle grass was present in landward portions of the transition zone (1000-1450 feet) as early as May 1993, it was present in such small quantities that it did not occur in any of the random quadrats. By October 1994, its abundance on Transect 1 had increased to such an extent that it occasionally occurred in some of the quadrats (Figure 12). However, the following year above ground portions of *Thalassia* were temporarily eliminated from this zone. Coverage remained low through October 1997, after which it once again began a steady increase. By October 1999, turtle grass occurred in about 25 percent of all survey quadrats 1000 to 1450 feet from shore. Another decline in turtle grass coverage occurred within this zone during 2000, and coverage remained relatively low through 2005, emphasizing the sensitivity of this species to changing water temperature patterns. However, since 2005 turtle grass coverage in landward portions of the transition zone has increased substantially, reaching a historical high of about 51% in 2009. Although coverage has declined somewhat over the last two years, it nevertheless remains at relatively high levels.

In 2008, turtle grass was documented within the inner basin (1,000 feet of the MODC) for the first time since 1994, when it was present in only 0.3% of all quadrats. Since 2008, turtle grass has been persistent in the inner basin and has gradually increased in coverage, reaching its historical high of 32% in the fall of 2011. This demonstrates that turtle grass is clearly capable of expanding its distribution shoreward into areas from which it was previously excluded during periods when summer water temperatures approach ambient conditions. However, it should be noted that this recent expansion is more likely a function of limited plant operation rather than a result of supplemental pumping. Temperature data collected throughout this study indicate that plant operations have been minimal since 2006.

Data collected since 1992 indicate that supplemental pumping during periods of plant operation resulted in demonstrable benefits to the seagrass communities within the Cutler embayment. However, despite the overall positive trends, it is apparent that temporary setbacks in seagrass conditions can occur during periods of sustained high water temperatures. The negative response of turtle grass to unusually high water temperatures is apparently exacerbated when high temperatures are accompanied by periods of heavy freshwater input, as presumably occurred during the summers of 1995 and 2004 (Hurricane Frances). Those setbacks are particularly noticeable when examining *Thalassia* coverage data for Transect 4, west of the MODC where the grasses appear to be particularly sensitive to periods of high water temperatures (Figure 15). Coverage within the transition zone (1500-1750 feet from the MODC) increased steadily after monitoring began, reaching nearly 85% in October 1994. However, following that survey, there was a substantial decline. Conditions west of the MODC began to improve quickly and coverage within the transition zone had reached 100% by the fall of 2003. However, during the summer of 2004, turtle grass experienced an even more dramatic decline, as it was almost completely displaced from the seaward portion of Transect 4. A sustained recovery from those high summer water temperatures did not begin until 2008, and turtle grass has yet to fully recover to pre-2004 conditions.

An overall long-term trend of improvement in seagrass conditions throughout the embayment has been observed since monitoring began. Data collected to date indicate that turtle grass has expanded its distribution shoreward into areas from which it was excluded prior to initiation of supplemental pumping. This expansion was a relatively slow process but now appears to be accelerating as a result of reduced plant operations. As demonstrated during 1995 and again in 2004, the seagrass community can be disrupted by unusual water quality conditions. When these disruptions occur, above ground portions of turtle grass are eliminated from some areas of the embayment. Then over a relatively short time frame, shoal grass begins to recolonize the resulting barren patches. Upon return of favorable water quality conditions turtle grass displaces shoal grass as the dominant species within these patches.

The seagrass community within the Cutler embayment has been shown to be robust and resilient. The overall improvement in seagrass community characteristics documented over the period of monitoring can best be explained as a response of the grasses to amelioration of high summer water temperatures resulting from implementation of supplemental pumping at PCU, and more recently, reduced plant operations.

SUMMARY AND CONCLUSIONS

1) Based on data from the 1000-, 1500- and 2000-foot stations, daily summer water temperatures within the Cutler embayment during 2011 were well below average, the result of limited plant operations. Temperatures most stressful to turtle grass occurred during the months of July and August. Warmest temperatures occurred in the late afternoon, and coolest temperatures were recorded in the morning. The average daily mean temperature for the warmest part of the summer (June-August) 1000, 1500 and 2000 feet from the MODC was 87.3°F (30.7°C), 87.1°F (30.6°C) and 86.5°F (30.3°C),

respectively. Hourly mean temperatures throughout the summer approached historical minimum values.

2) Temperatures in excess of 35°C occurred on average less than 0.2 hr per day at the 1000-foot station and occurred even less frequently at the more distant locations. Consequently, exposure of grasses to potentially stressful high water temperatures was well below the historical averages for each station. Conversely, periods of thermal relief (temperatures below 32°C) during 2011 were longer than the corresponding historical averages.

3) Changes in seagrass conditions between April and October 2011 were most apparent in the inner basin, where turtle grass had migrated in a landward direction in most areas of the embayment. Elsewhere, conditions were very similar.

4) Long-term improvements in seagrass coverage, density, and biomass within the Cutler embayment are evident from data collected between October 1991, prior to initiation of supplemental pumping, and October 2011. Improvements include:

   a) An overall increase in the coverage, density, and biomass of shoal grass within the inner basin,
   b) A general decrease in the size of the area around the MODC containing little or no seagrasses,
   c) An overall increase in the coverage, density, and biomass of turtle grass throughout the embayment,
   d) Replacement of shoal grass by turtle grass as the most dominant species within many areas of the transition zone, and
   e) A gradual shoreward expansion in the distribution of turtle grass.

   These data support model predictions of improved thermal conditions within the embayment coincident with initiation of supplemental pumping.

5) Notwithstanding the positive trends documented above, improvements within the seagrass community at Cutler, particularly those related to turtle grass, were relatively slow during periods of persistent plant operations. Periodic declines in seagrass conditions have occurred during summers of unusually high water temperatures, and these setbacks appear to be exacerbated if high temperatures are accompanied by periods of low salinity. However, these setbacks are temporary, with seagrass coverage, biomass, and density increasing upon return of more favorable water quality conditions.

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Table 1

Cutler Plant Seagrass Monitoring
October 3, 2011 - Transect No. 1

Zone Characteristics	Distance from MODC (ft)	Density of all Grasses	Species	Percent Coverage
0-350' Exposed rock within dredged channel with scattered sparse *Halodule*				
350-550' Uniform coverage of dense *Halodule*	400	Dense	*Halodule*	100.0
	500	Dense	*Halodule*	100.0
550-750' Dense *Halodule* with widely scattered *Thalassia*	600	Dense	*Halodule*	100.0
			Thalassia	14.6
	700	Dense	*Halodule*	100.0
			Thalassia	25.0
750-1350' Transition zone where *Halodule and Thalassia* merge	800	Dense	*Thalassia*	100.0
			Halodule	66.7
	900	Dense	*Thalassia*	81.3
			Halodule	91.7
	1000	Dense	*Halodule*	100.0
	1100	Dense	*Halodule*	100.0
			Thalassia	12.5
	1200	Dense	*Halodule*	100.0
	1300	Dense	*Halodule*	100.0
			Thalassia	16.7
1350'-2400' *Thalassia* displaces *Halodule*	1400	Dense	*Thalassia*	100.0
	1500	Dense	*Thalassia*	100.0
	1600	Dense	*Thalassia*	100.0
	1700	Dense	*Thalassia*	100.0
	1800	Dense	*Thalassia*	100.0
	1900	Moderate	*Thalassia*	100.0
			Halodule	66.7
	2000	Dense	*Thalassia*	100.0
	2100	Dense	*Thalassia*	100.0
	2200	Moderate	*Thalassia*	100.0
	2300	Moderate	*Thalassia*	100.0
	2400	Sparse	*Halodule*	100.0
			Thalassia	4.2

Table 2

Cutler Plant Seagrass Monitoring
October 3, 2011 - Transect No. 2

Zone Characteristics	Distance from MODC (ft)	Density of all Grasses	Species	Percent Coverage
0-150' Exposed rock near shore with scattered sparse *Halodule* in between	100	Dense	*Halodule*	100.0
150-450' Dense *Halodule*	200	Dense	*Halodule*	100.0
	300	Dense	*Halodule*	100.0
	400	Dense	*Halodule*	100.0
450-950' Dense *Halodule* with widely scattered *Thalassia*	500	Dense	*Halodule*	100.0
			Thalassia	37.5
	600	Dense	*Halodule*	100.0
	700	Dense	*Halodule*	100.0
	800	Dense	*Halodule*	100.0
	900	Dense	*Halodule*	100.0
950-1550' Transition zone where distributions of *Halodule* and *Thalassia* merge	1000	Dense	*Halodule*	100.0
			Thalassia	25.0
	1100	Moderate	*Halodule*	100.0
			Thalassia	29.2
	1200	Moderate	*Halodule*	100.0
			Thalassia	41.7
	1300	Dense	*Halodule*	100.0
			Thalassia	25.0
	1400	Dense	*Halodule*	100.0
			Thalassia	33.3
	1500	Dense	*Thalassia*	100.0
			Halodule	100.0
1550-2400' *Thalassia* displaces *Halodule*	1600	Dense	*Thalassia*	100.0
	1700	Dense	*Thalassia*	100.0
	1800	Dense	*Thalassia*	100.0
	1900	Dense	*Thalassia*	100.0
	2000	Dense	*Thalassia*	100.0
	2100	Dense	*Thalassia*	100.0
	2200	Dense	*Thalassia*	100.0
	2300	Dense	*Thalassia*	100.0
	2400	Dense	*Thalassia*	100.0

Table 3

Cutler Plant Seagrass Monitoring
October 3, 2011 - Transect No. 3

Zone Characteristics	Distance from MODC (ft)	Density of all Grasses	Species	Percent Coverage
50-150' Moderate *Halodule*	100	Moderate	*Halodule*	100.0
150-350' Dense *Halodule*	200	Dense	*Halodule*	100.0
	300	Dense	*Halodule*	100.0
350-1150' Moderate to dense *Halodule* with widely scattered *Thalassia*	400	Dense	*Halodule*	100.0
			Thalassia	4.2
	500	Dense	*Halodule*	100.0
	600	Moderate	*Halodule*	91.7
			Thalassia	33.3
	700	Dense	*Halodule*	100.0
			Thalassia	50.0
	800	Moderate	*Halodule*	100.0
			Thalassia	20.8
	900	Dense	*Halodule*	100.0
			Thalassia	20.8
	1000	Moderate	*Halodule*	100.0
	1100	Moderate	*Halodule*	100.0
1150-1450' Transition zone where distributions of *Halodule* and *Thalassia* merge	1200	Moderate	*Thalassia*	100.0
			Halodule	95.8
	1300	Moderate	*Halodule*	100.0
			Thalassia	29.2
	1400	Dense	*Halodule*	100.0
			Thalassia	25.0
1450-2400' *Thalassia* largely displaces *Halodule*	1500	Moderate	*Thalassia*	100.0
	1600	Moderate	*Thalassia*	100.0
			Halodule	50.0
	1700	Dense	*Thalassia*	100.0
	1800	Moderate	*Thalassia*	100.0
			Halodule	37.5
	1900	Moderate	*Thalassia*	81.3
			Halodule	100.0
	2000	Moderate	*Thalassia*	100.0
	2100	Dense	*Thalassia*	100.0
	2200	Dense	*Thalassia*	100.0
	2300	Dense	*Thalassia*	100.0
	2400	Dense	*Thalassia*	100.0

Table 4

Cutler Plant Seagrass Monitoring
October 3, 2011 - Transect No. 4

Zone Characteristics	Distance from MODC (ft)	Density of all Grasses	Species	Percent Coverage
0-50' Exposed rock within channel				
50-550' Moderate to dense *Halodule*	100	Moderate	*Halodule*	100.0
	200	Dense	*Halodule*	100.0
	300	Dense	*Halodule*	100.0
	400	Dense	*Halodule*	100.0
	500	Dense	*Halodule*	100.0
550-850' Moderate to dense *Halodule* with widely scattered *Thalassia*	600	Moderate	*Halodule*	100.0
			Thalassia	12.5
	700	Moderate	*Halodule*	100.0
			Thalassia	33.3
	800	Dense	*Halodule*	100.0
			Thalassia	8.3
850-1250' Transition zone where distributions of *Halodule* and *Thalassia* merge	900	Dense	*Halodule*	100.0
			Thalassia	75.0
	1000	Dense	*Halodule*	87.5
			Thalassia	83.3
	1100	Dense	*Thalassia*	100.0
			Halodule	100.0
	1200	Moderate	*Thalassia*	95.8
			Halodule	100.0
1250-1800' Mostly sparse *Halodule* with scattered *Thalassia*	1300	Sparse	*Halodule*	100.0
			Thalassia	45.8
	1400	Moderate	*Halodule*	100.0
			Thalassia	33.3
	1500	Sparse	*Halodule*	100.0
			Thalassia	16.7
	1600	Sparse	*Halodule*	100.0
			Thalassia	12.5
	1700	Sparse	*Halodule*	100.0
			Thalassia	41.7
	1800	Sparse	*Halodule*	100.0
			Thalassia	64.6

Table 5

Cutler Plant Seagrass Monitoring
October 3, 2011 - Transect No. 5

Zone Characteristics	Distance from MODC (ft)	Density of all Grasses	Species	Percent Coverage
0-150' Exposed rock near shore with scattered *Halodule* in between				
150-350' Dense *Halodule*	200	Dense	*Halodule*	100.0
	300	Dense	*Halodule*	100.0
350-1150' Moderate to dense *Halodule* with widely scattered *Thalassia*	400	Dense	*Halodule*	100.0
			Thalassia	25.0
	500	Dense	*Halodule*	100.0
			Thalassia	58.3
	600	Dense	*Halodule*	100.0
	700	Dense	*Halodule*	100.0
			Thalassia	25.0
	800	Moderate	*Halodule*	100.0
	900	Dense	*Halodule*	100.0
	1000	Dense	*Halodule*	100.0
	1100	Dense	*Halodule*	100.0
			Thalassia	8.3
1150-1450' Transition zone where distributions of *Halodule* and *Thalassia* merge	1200	Moderate	*Halodule*	100.0
			Thalassia	25.0
	1300	Moderate	*Halodule*	100.0
			Thalassia	58.3
	1400	Moderate	*Halodule*	100.0
			Thalassia	4.2
1450-2400' *Thalassia* displaces *Halodule*	1500	Dense	*Thalassia*	100.0
	1600	Dense	*Thalassia*	100.0
	1700	Dense	*Thalassia*	100.0
	1800	Dense	*Thalassia*	100.0
	1900	Dense	*Thalassia*	100.0
	2000	Sparse	*Halodule*	100.0
			Thalassia	25.0
	2100	Dense	*Thalassia*	100.0
	2200	Moderate	*Thalassia*	100.0
	2300	Dense	*Thalassia*	100.0
	2400	Dense	*Thalassia*	100.0

Table 6

Cutler Plant Seagrass Monitoring
October 3, 2011 - Transect No. 6

Zone Characteristics	Distance from MODC (ft)	Density of all Grasses	Species	Percent Coverage
50-250' Dense *Halodule*	100	Dense	*Halodule*	100.0
	200	Dense	*Halodule*	100.0
250-1250' Moderate to dense *Halodule* with widely scattered *Thalassia*	300	Moderate	*Thalassia*	70.8
			Halodule	33.3
	400	Dense	*Halodule*	100.0
	500	Dense	*Halodule*	100.0
	600	Dense	*Halodule*	100.0
			Thalassia	91.7
	700	Dense	*Halodule*	100.0
	800	Dense	*Halodule*	100.0
			Thalassia	27.1
	900	Dense	*Halodule*	100.0
			Thalassia	16.7
	1000	Moderate	*Halodule*	100.0
	1100	Dense	*Halodule*	100.0
	1200	Moderate	*Halodule*	100.0
			Thalassia	12.5
1250-1450' Transition zone where distributions of *Halodule* and *Thalassia* merge	1300	Moderate	*Halodule*	100.0
			Thalassia	33.3
	1400	Dense	*Halodule*	89.6
			Thalassia	70.8
1450-2400' *Thalassia* displaces *Halodule*	1500	Dense	*Thalassia*	100.0
	1600	Dense	*Thalassia*	100.0
	1700	Dense	*Thalassia*	100.0
	1800	Dense	*Thalassia*	100.0
	1900	Dense	*Thalassia*	100.0
	2000	Moderate	*Thalassia*	100.0
			Halodule	75.0
	2100	Dense	*Thalassia*	100.0
	2200	Dense	*Thalassia*	100.0
			Halodule	25.0
	2300	Dense	*Thalassia*	100.0
	2400	Dense	*Thalassia*	100.0

Table 7. Summary of Annual Summer (June 1 Through August 31) Water Temperatures, Transect 1, Cutler Plant.

Distance from MODC[1] (feet)	Year	Daily Mean Temperatures (°C)[2]		Daily Minimum Temperatures (°C)[3]		Daily Maximum Temperatures (°C)[4]	
		Mean	Range	Mean	Range	Mean	Range
1000	2011	30.7 ± 1.6	27.6 – 33.9	29.4 ± 1.6	26.0 – 33.2	32.3 ± 1.8	28.4 – 35.9
	Historical Average (1993-2010)[5]	32.4 ± 1.9	24.3 – 38.0	30.7 ± 1.7	23.6 – 35.7	34.6 ± 2.5	25.2 – 41.3
	Historical Maximum (1998)	34.5 ± 1.4	30.8 – 36.9	32.6 ± 1.2	29.3 – 35.1	37.0 ± 1.8	32.0 – 39.8
	Historical Minimum (2008)	30.9 ± 1.6	27.1 – 34.6	29.5 ± 1.4	26.1 – 32.5	32.6 ± 2.1	28.2 – 38.5
1500	2011	30.6 ± 1.6	27.6 – 33.5	29.4 ± 1.5	26.2 – 32.0	31.8 ± 1.7	28.4 – 35.0
	Historical Average (1993-2010)[6]	31.9 ± 1.8	24.0 – 37.1	30.5 ± 1.7	22.6 - 35.4	33.7 ± 2.2	24.8 – 40.3
	Historical Maximum (1998)	33.7 ± 1.2	30.9 - 35.7	32.2 ± 1.1	29.7 - 34.9	35.6 ± 1.6	31.3 - 38.4
	Historical Minimum (2008)	30.8 ± 1.5	27.1 – 33.8	29.5 ± 1.4	26.2 – 33.0	32.2 ± 1.7	28.1 – 36.4
2000	2011	30.3 ± 1.6	27.5 – 33.2	29.2 ± 1.5	26.0 – 31.9	31.6 ± 1.7	28.1 – 34.8
	Historical Average (1993-2010)	31.6 ± 1.7	23.5 – 36.5	30.3 ± 1.6	22.3 – 35.0	33.4 ± 2.1	24.8 – 39.7
	Historical Maximum (1998)	33.1 ± 1.2	30.0 - 35.5	31.6 ± 1.1	29.3 - 33.8	35.4 ± 1.9	30.5 - 38.7
	Historical Minimum (2008)	30.6 ± 1.4	27.2 – 33.3	29.5 ± 1.4	26.2 – 32.2	31.9 ± 1.6	28.1 – 35.4

[1] MODC = Mouth of discharge canal; [2] Average of daily averages (24 hourly readings each day) over the period of comparison; [3] Average of minimum hourly readings recorded each day over period of record; [4] Average of maximum hourly readings recorded each day over period of record; [5] No data available for 1993, 1999-2001; [6] No data available for 2000.

Table 8. Percentage of All Hourly Summer (June 1 through August 31) Water Temperatures Greater Than Specified Thresholds, Cutler Plant, 1993-2011.

Threshold Temperature (Temperatures >)	Year	Distance from MODC (feet)[1]		
		1000	1500	2000
32.0°C (89.6°F)	2011	25.4	22.3	18.7
	Historical Average (1993-2010)	52.7[2]	49.4[3]	44.1[4]
	Historical Max (Yr)	89.2 (1998)	81.5 (1998)	72.3 (1998)
	Historical Min (Yr)	26.7 (2008)	24.3 (2008)	22.0 (2008)
34.0°C (93.2°F)	2011	4.5	2.8	1.4
	Historical Average (1993-2010)	24.5[2]	17.9[3]	12.2[4]
	Historical Max (Yr)	56.6 (1998)	37.0 (1998)	27.2 (1998)
	Historical Min (Yr)	4.1 (2009)	2.7 (2008)	1.3 (2008)
35°C (95.0°F)	2011	0.9	0.1	0.0
	Historical Average (1993-2010)	15.8[2]	8.6[3]	4.5[4]
	Historical Max (Yr)	36.8 (1998)	19.3 (1998)	14.0 (2001)
	Historical Min (Yr)	0.6 (2009)	0.1 (2009)	0.0 (2009)
36°C (96.8°F)	2011	0.0	0.0	0.0
	Historical Average (1993-2010)	9.7[2]	4.6[3]	2.2[4]
	Historical Max (Yr)	25.3 (1998)	11.2 (1998)	9.6 (1998)
	Historical Min (Yr)	0.0 (2009)	0.0 (2009/10)	0.0 (2008-10)

[1] MODC = Mouth of discharge canal.
[2] No data available for 1993, 1999-2001.
[3] No data or incomplete data available for 1993, 2000-2001.
[4] Incomplete data available for 1993, 2001.

Table 9. Comparison of Above-ground Seagrass Biomass Between Spring and Fall Survey Periods, Cutler Plant, 1993-2011.

SPECIES	DISTANCE FROM MODC (ft)	*MEAN LEAF BIOMASS (g/m^2) By SURVEY PERIOD*									
		SPRING SURVEYS					FALL SURVEYS				
		1993-2010				2011	1993-2010				2011
		Min	Max	Mean	Std Dev	Value	Min	Max	Mean	Std Dev	Value
Halodule	300	0.0	93.1	32.1	31.6	62.8	0.0	122.9	25.0	34.7	106.9
	600	0.0	110.3	48.7	31.2	108.4	0.0	122.5	45.7	38.8	108.8
	1200	49.6	105.8	73.5	17.9	84.2	24.9	115.7	69.8	25.7	84.4
	1800	0.0	25.5	6.0	6.8	0.9	0.0	13.5	3.0	3.4	0.0
	2400	0.0	4.5	0.8	1.4	1.0	0.0	11.7	0.8	2.7	1.8
Thalassia	300	0.0	4.7	0.3	1.1	0.0	0.0	0.0	0.0	0.0	19.9
	600	0.0	74.0	4.1	17.4	1.8	0.0	0.0	0.0	0.0	21.5
	1200	0.0	18.5	3.1	5.8	50.6	0.0	29.6	3.7	8.7	131.9
	1800	108.8	484.3	288.2	113.4	282.2	99.7	341.3	237.2	70.7	341.3
	2400	173.9	579.7	403.3	125.4	348.5	155.7	450.8	309.5	71.9	331.6

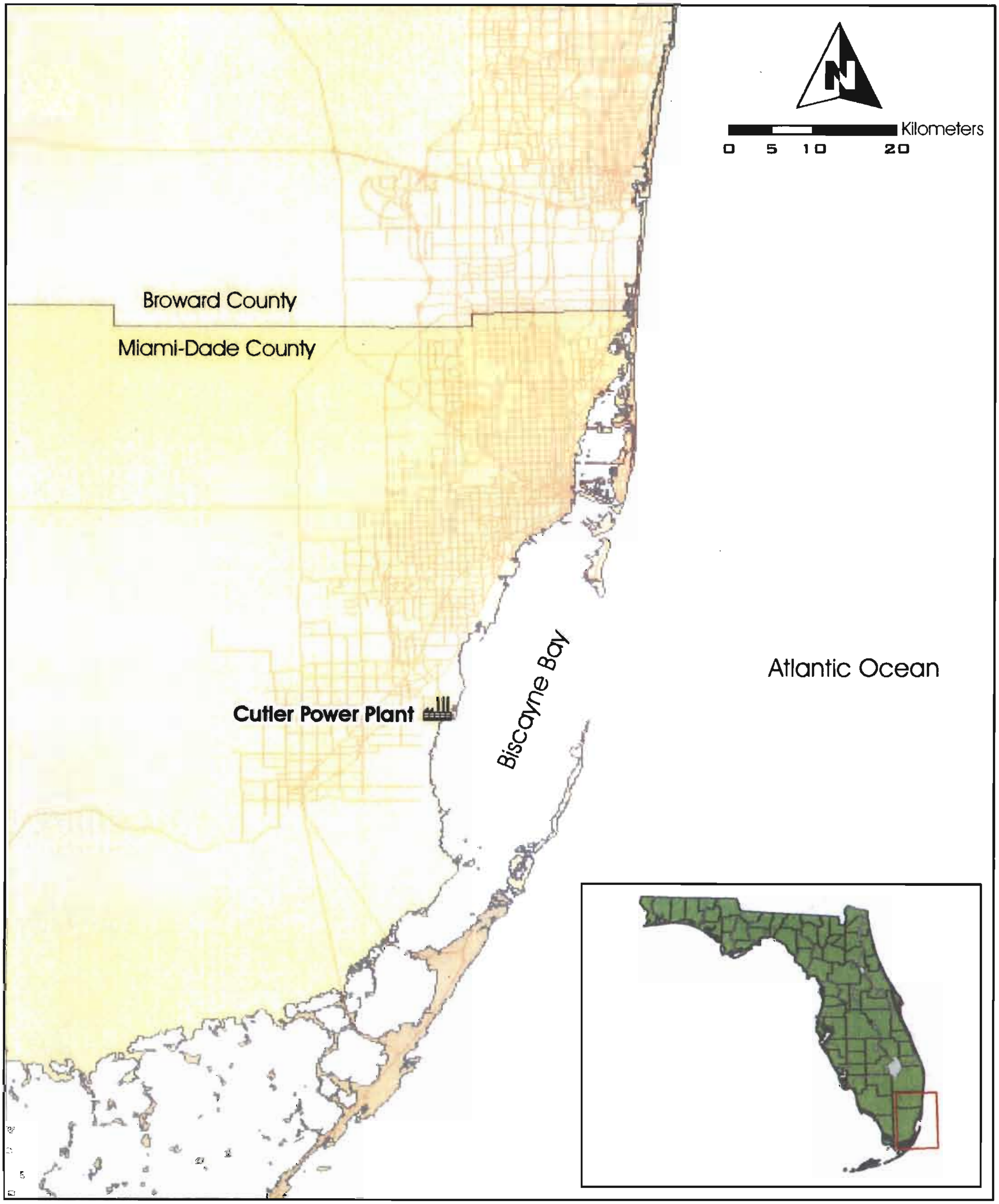

Figure 1. Location of the FPL Cutler Power Plant.

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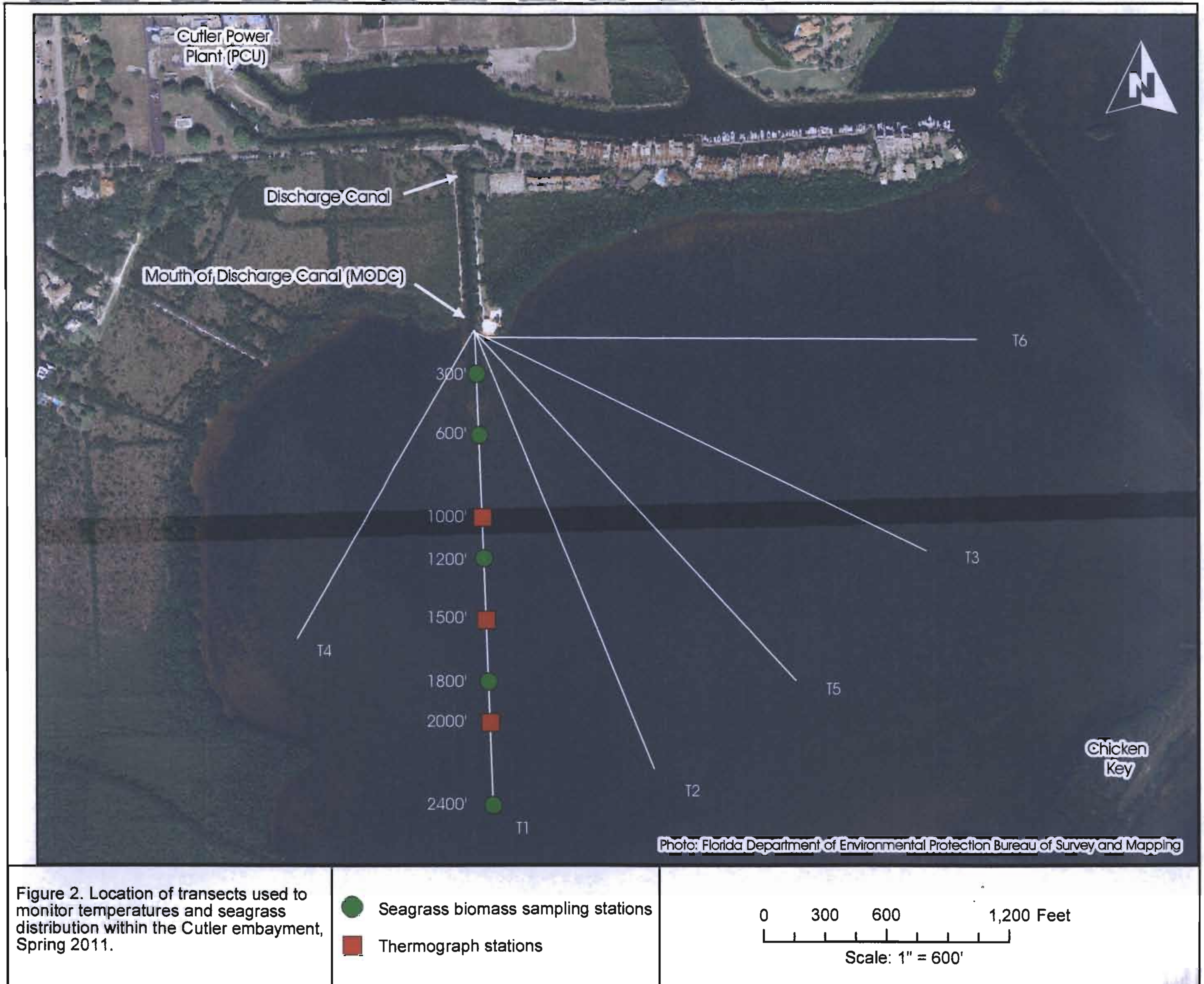

Figure 2. Location of transects used to monitor temperatures and seagrass distribution within the Cutler embayment, Spring 2011.

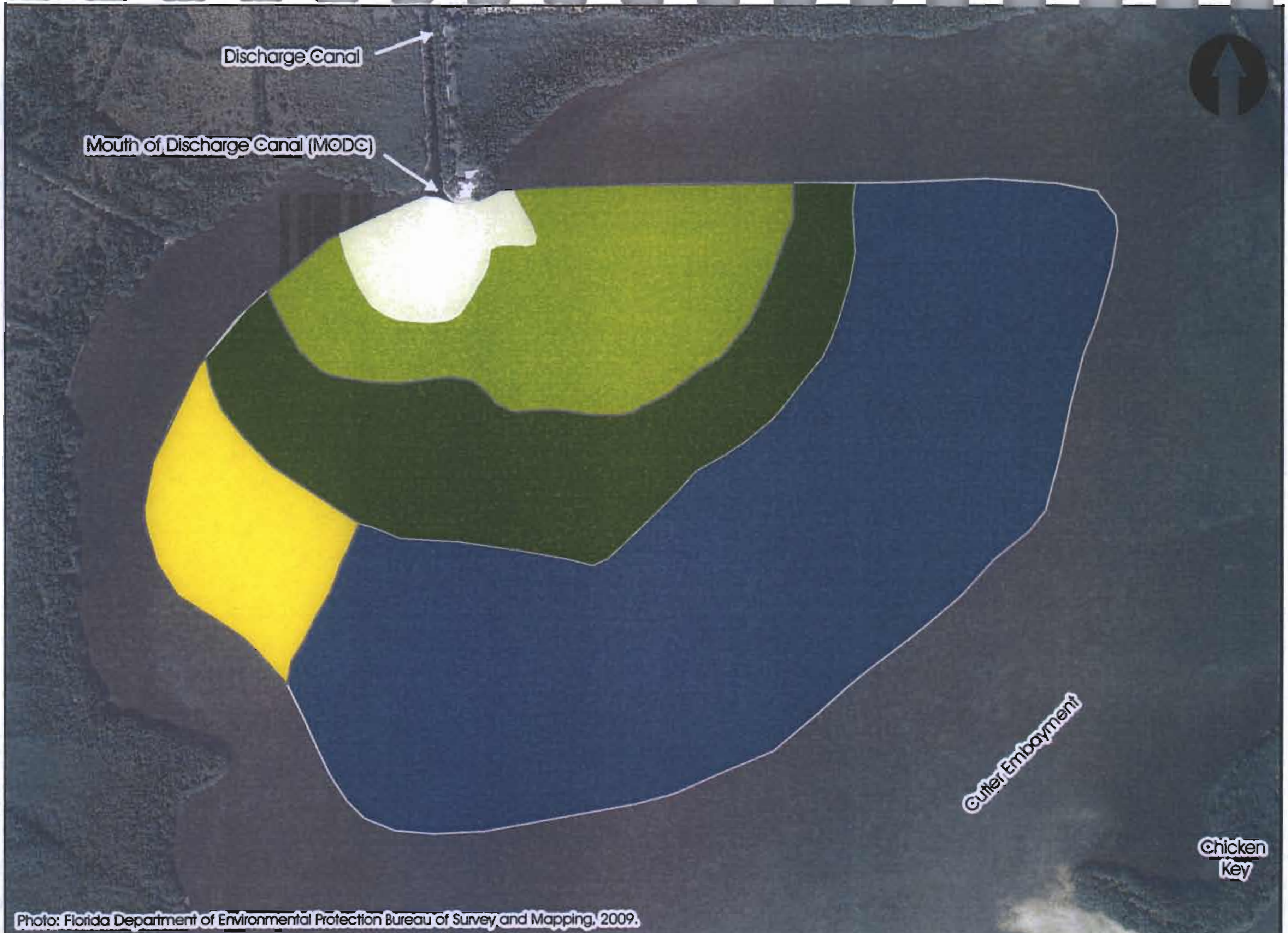

Figure 3. Distribution of seagrasses in the Cutler embayment, Fall 2011.

Scale: 1" = 500'

- No above ground seagrasses.
- Mostly dense shoal grass with widely scattered turtle grass
- Sparse to moderate coverage of shoal grass interspersed with sparse turtle grass
- Uniform moderate to dense coverage of shoal grass
- Dense coverage of intermixed shoal grass and turtle grass (Transition Zone)
- Dense coverage of turtle grass interspersed with shoal grass

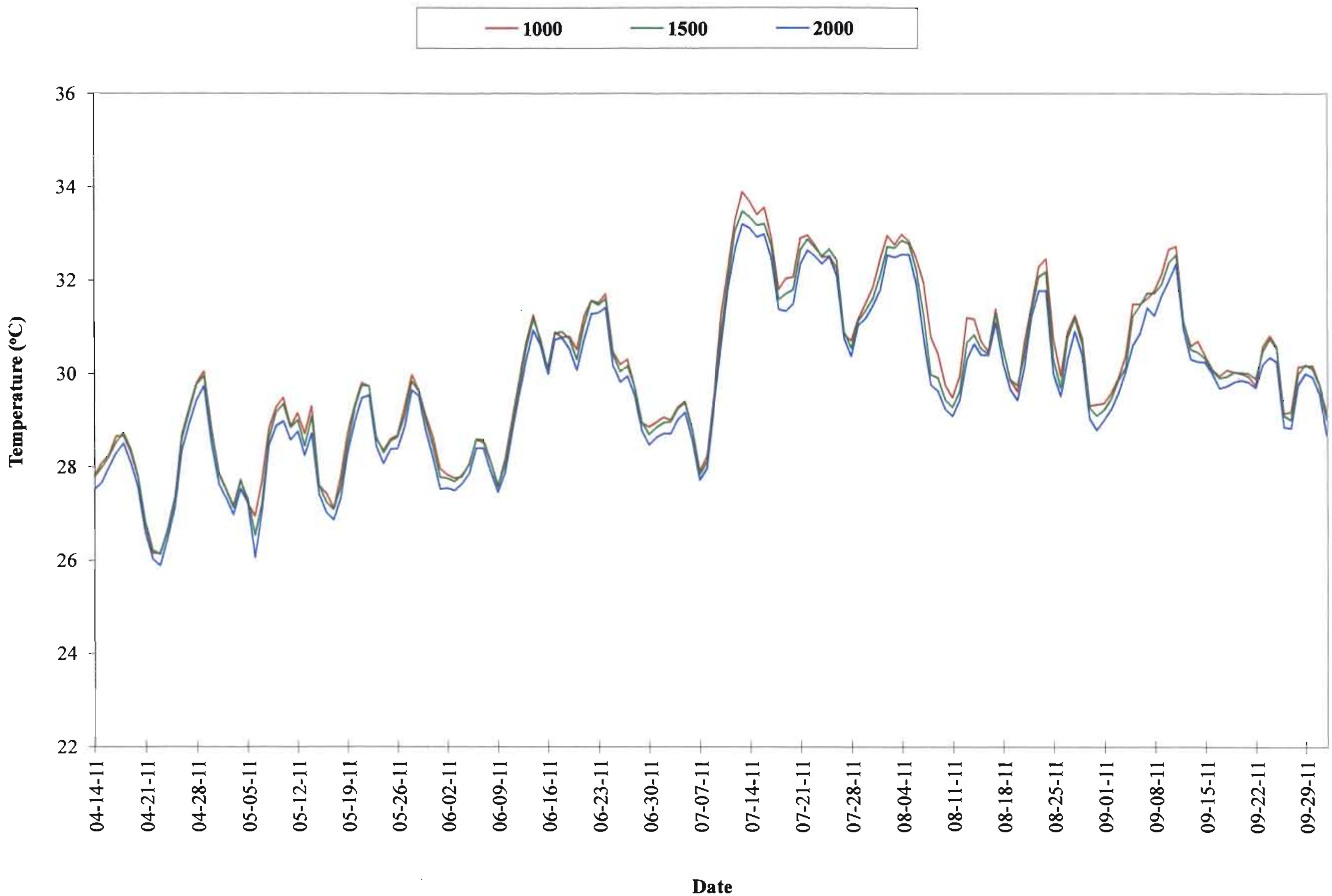

Figure 4. Average daily water temperatures at each monitoring station, Cutler Plant, April 14 through October 2, 2011.

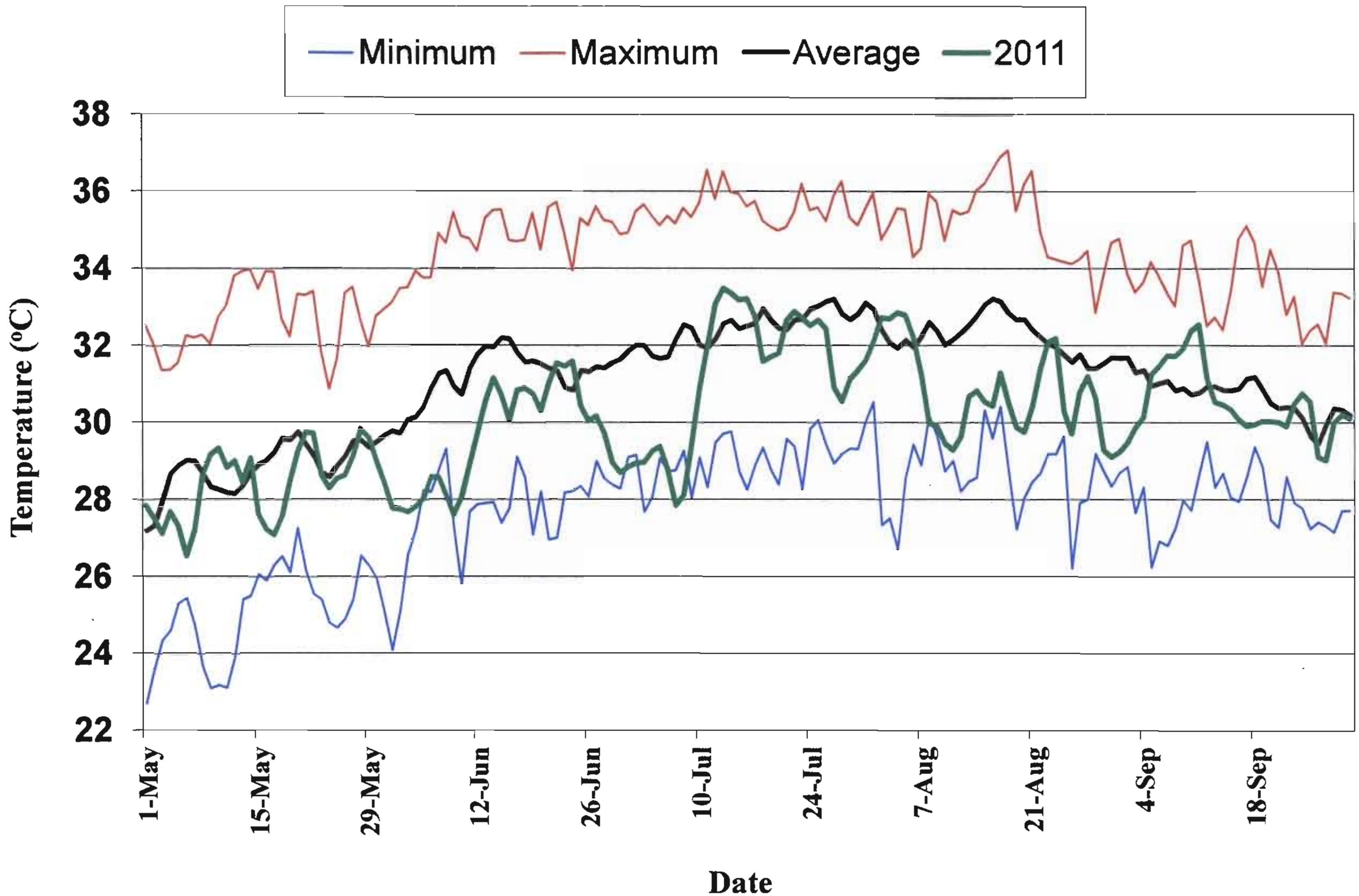

Figure 5. Comparison of average daily water temperatures 1500 feet from the MODC during the summer of 2011 (May 1 through September 30) with corresponding historical (1993-2010) average, minimum and maximum values.

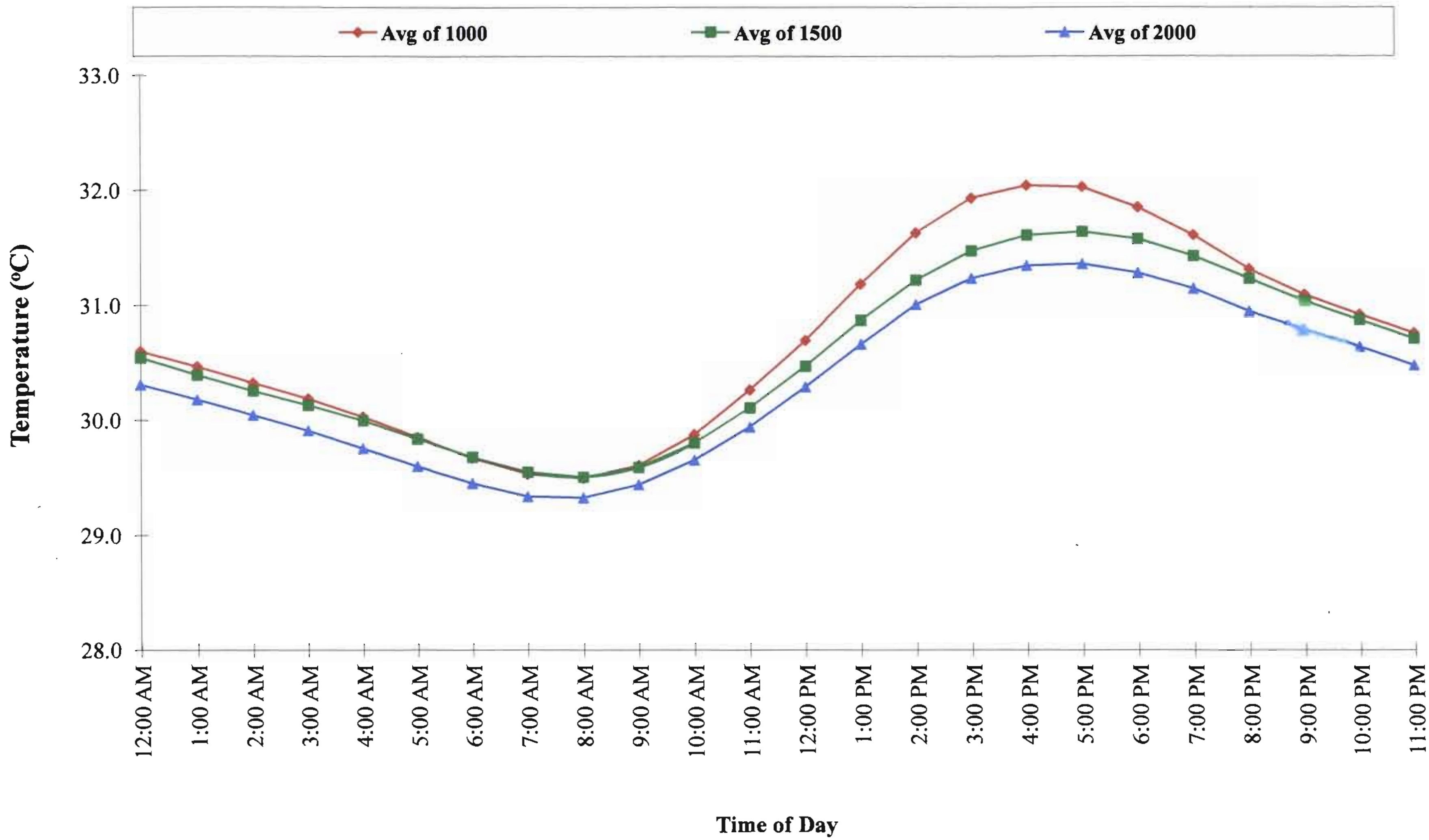

Figure 6. Comparison of mean hourly water temperatures 1000, 1500 and 2000 feet from MODC, Transect 1, Cutler Plant, June 1 through August 31, 2011.

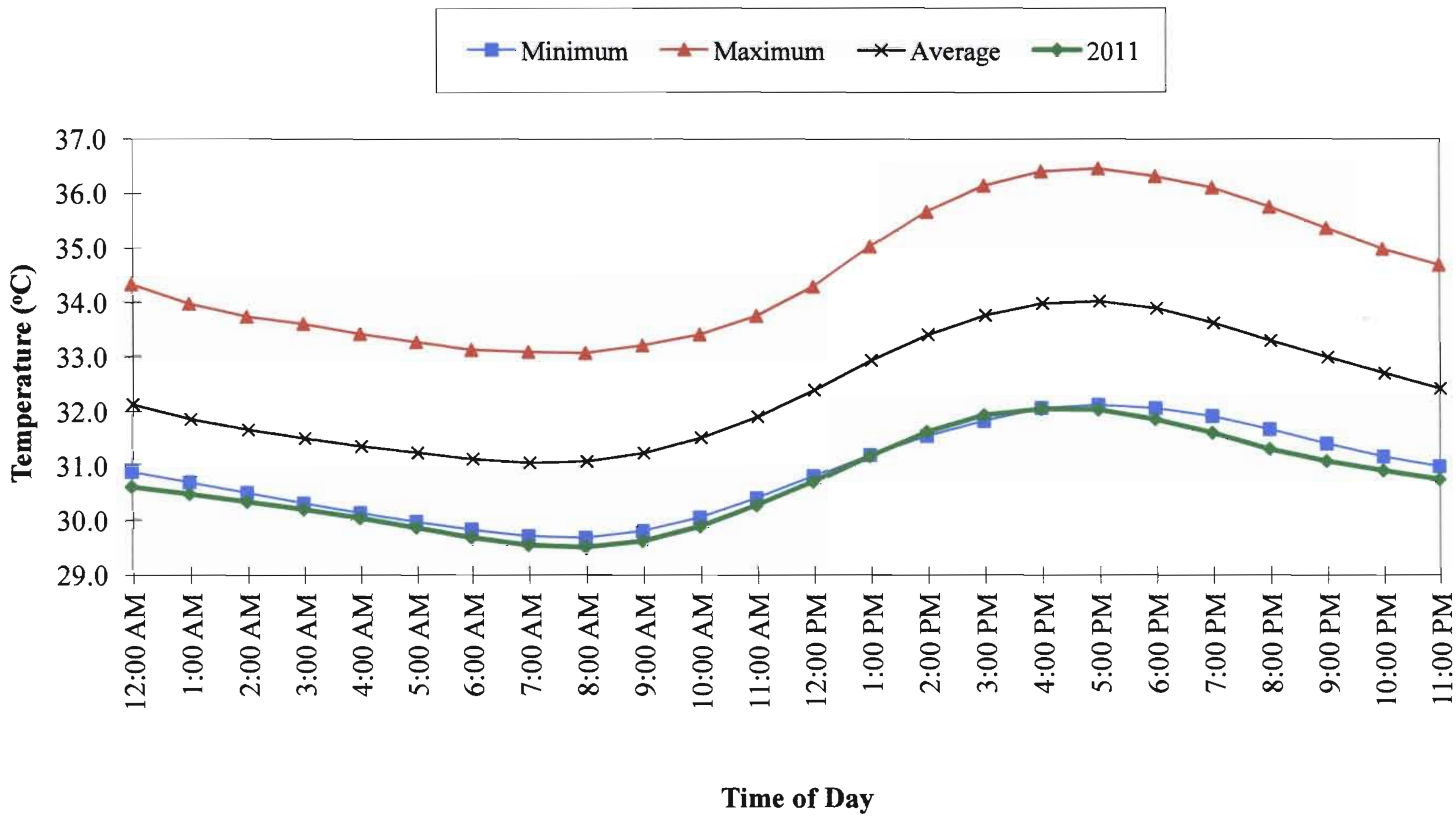

Figure 7. Average hourly summer (June 1 through August 31) water temperatures 1000 feet from the MODC in 2011 compared to historical (1993-2010) average, minimum, and maximum values, Cutler Plant.

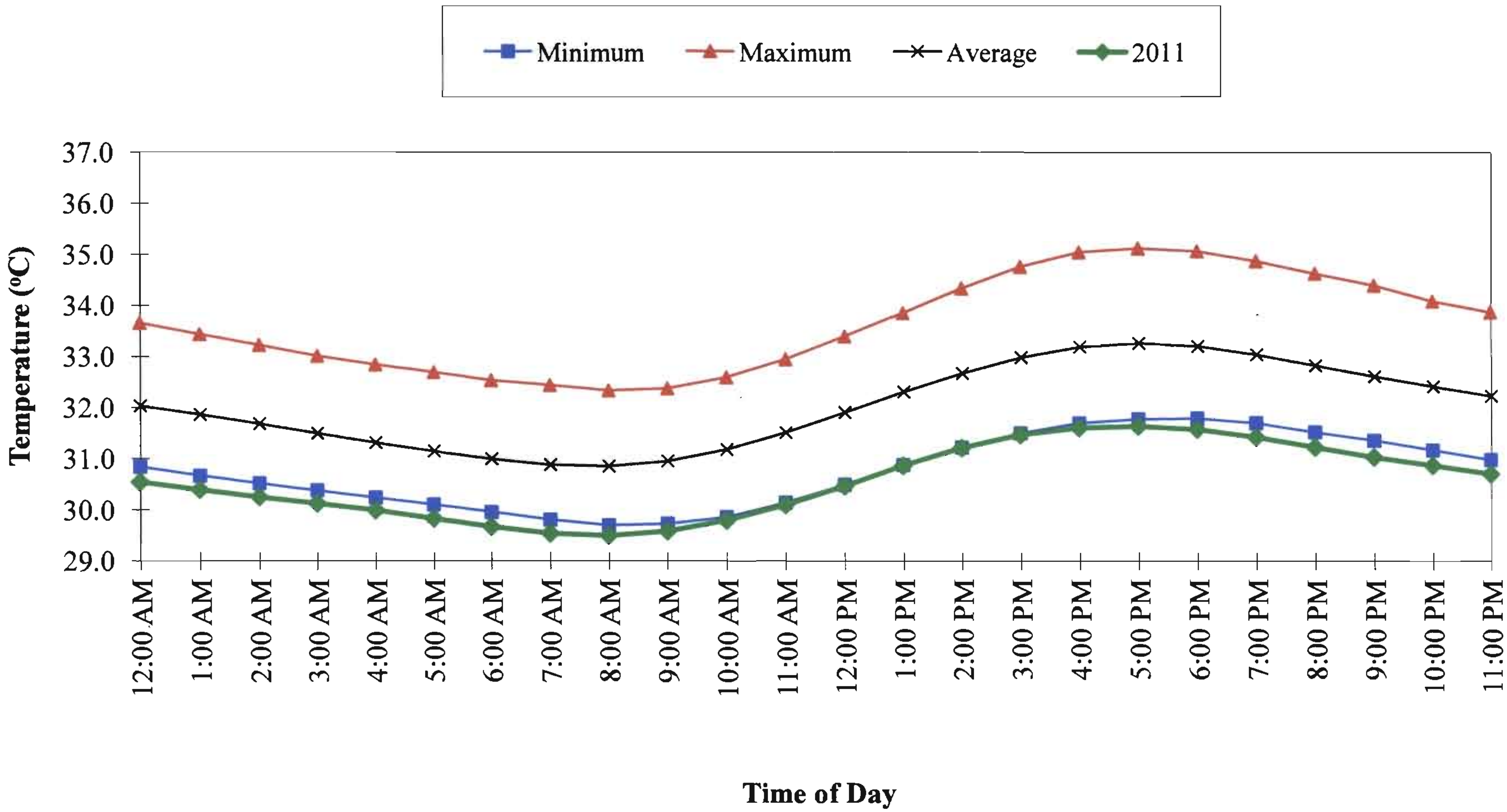

Figure 8. Average hourly summer (June 1 through August 31) water temperatures 1500 feet from the MODC in 2011 compared to historical (1993-2010) average, minimum, and maximum values, Cutler Plant.

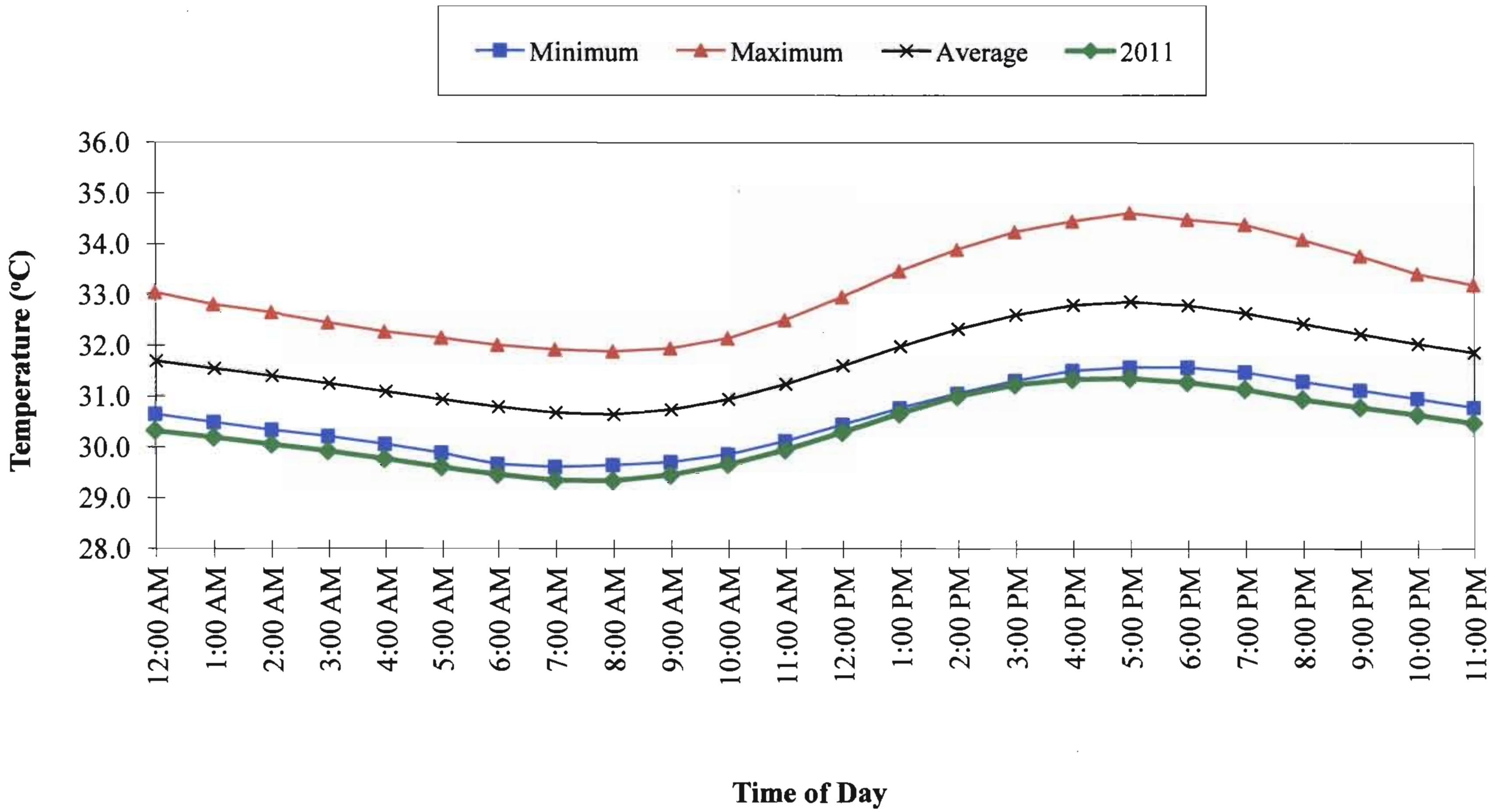

Figure 9. Average hourly summer (June 1 through August 31) water temperatures 2000 feet from the MODC in 2011 compared to historical (1993-2010) average, minimum, and maximum values, Cutler Plant.

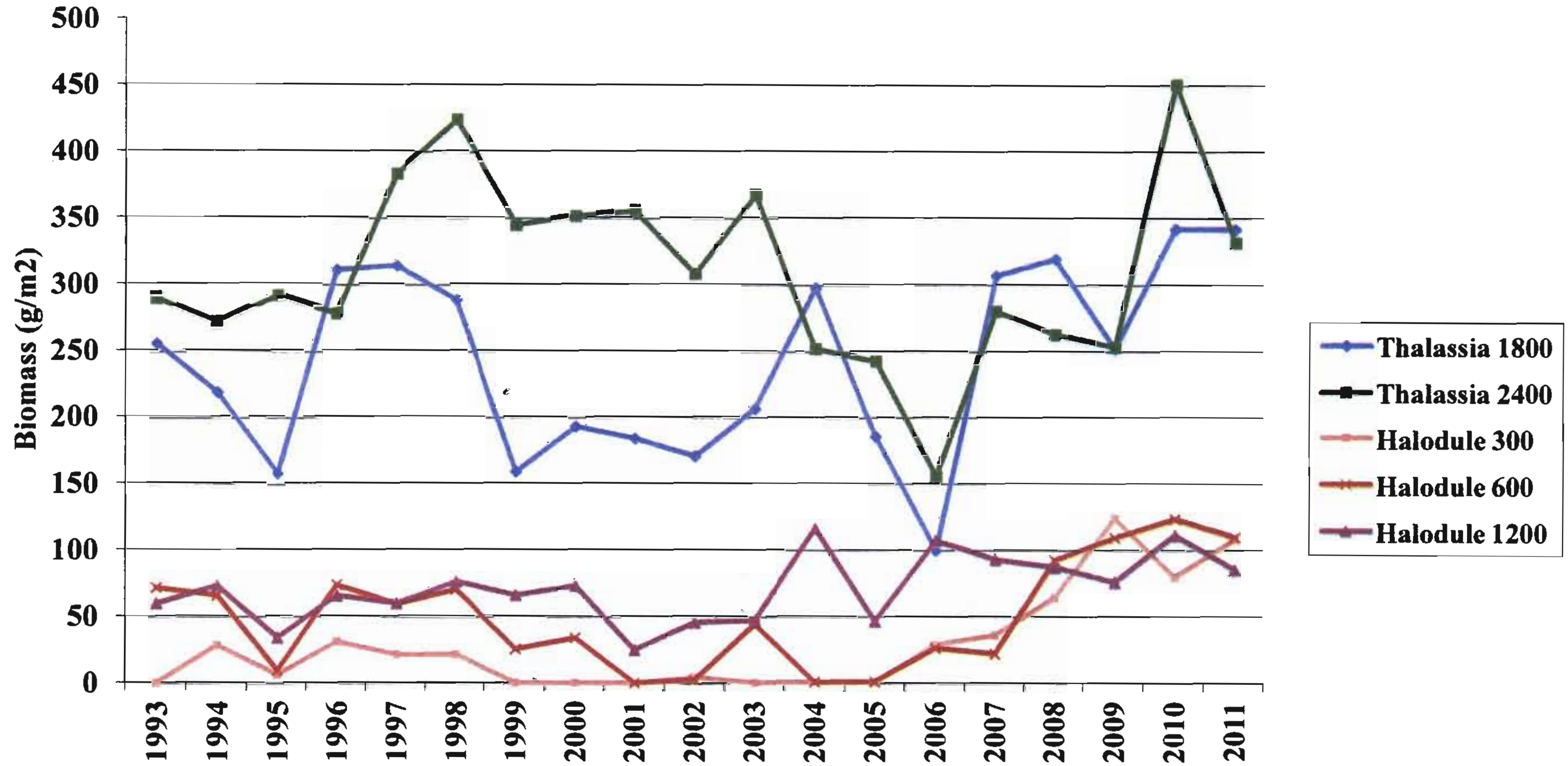

Figure 10. Long-term pattern of turtle grass and shoal grass biomass at various distances from shore along Transect 1 within the Cutler Embayment, fall surveys, 1993-2011.

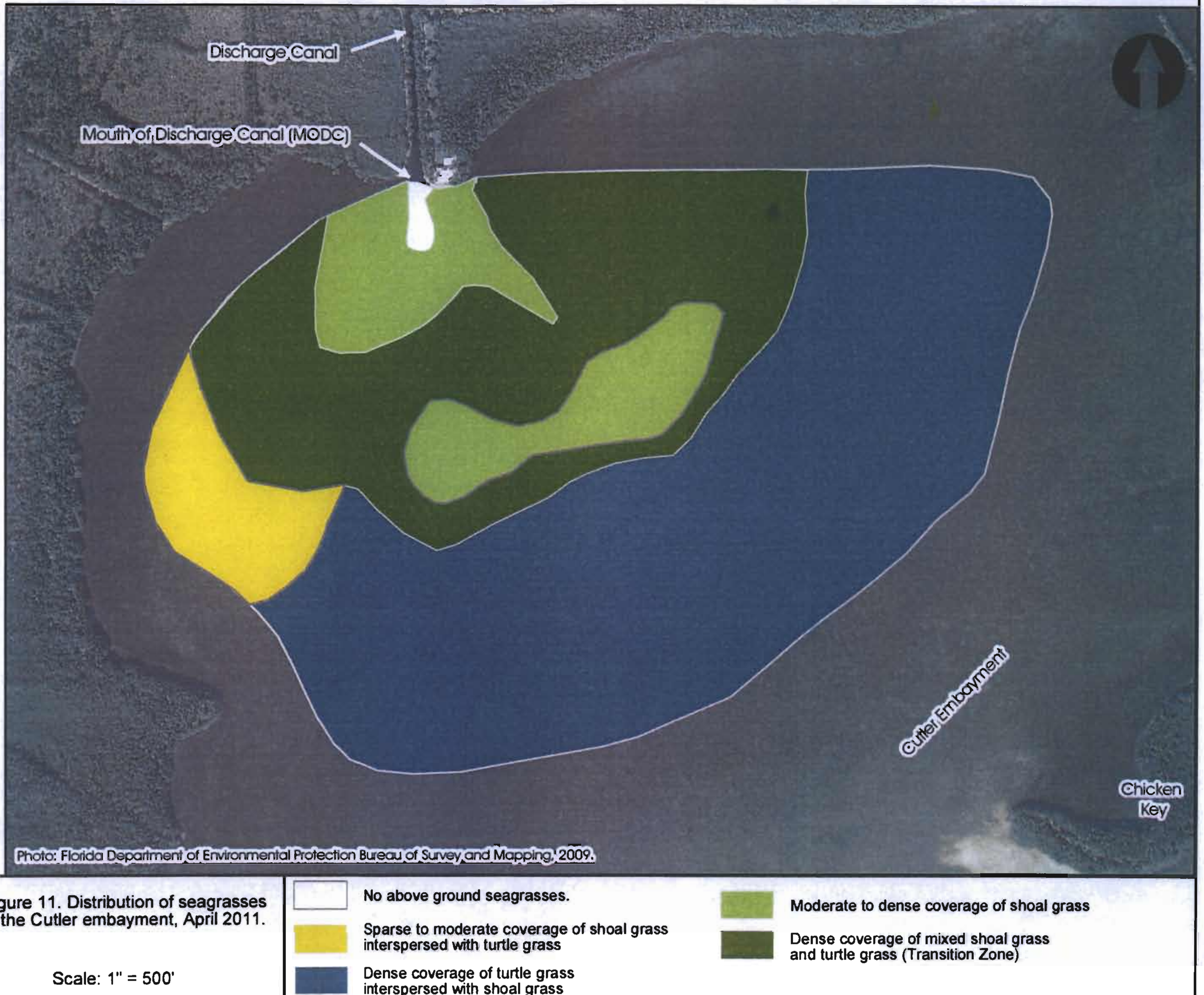

Figure 11. Distribution of seagrasses in the Cutler embayment, April 2011.

Scale: 1" = 500'

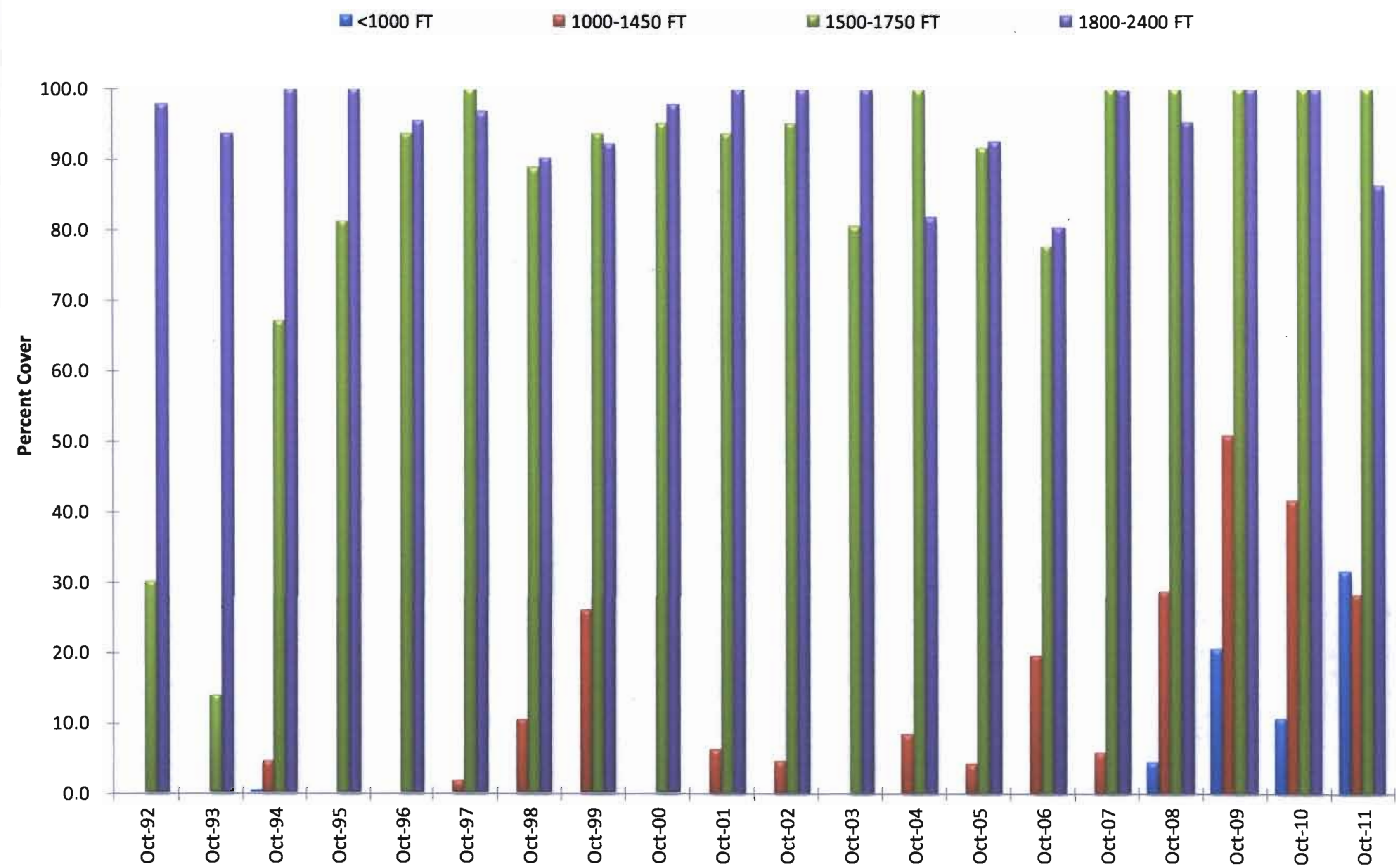

Figure 12. **Percent coverage of Turtle grass, *Thalassia testudinum*, along Transect 1 Cutler embayment, October 1992 - October 2011.**

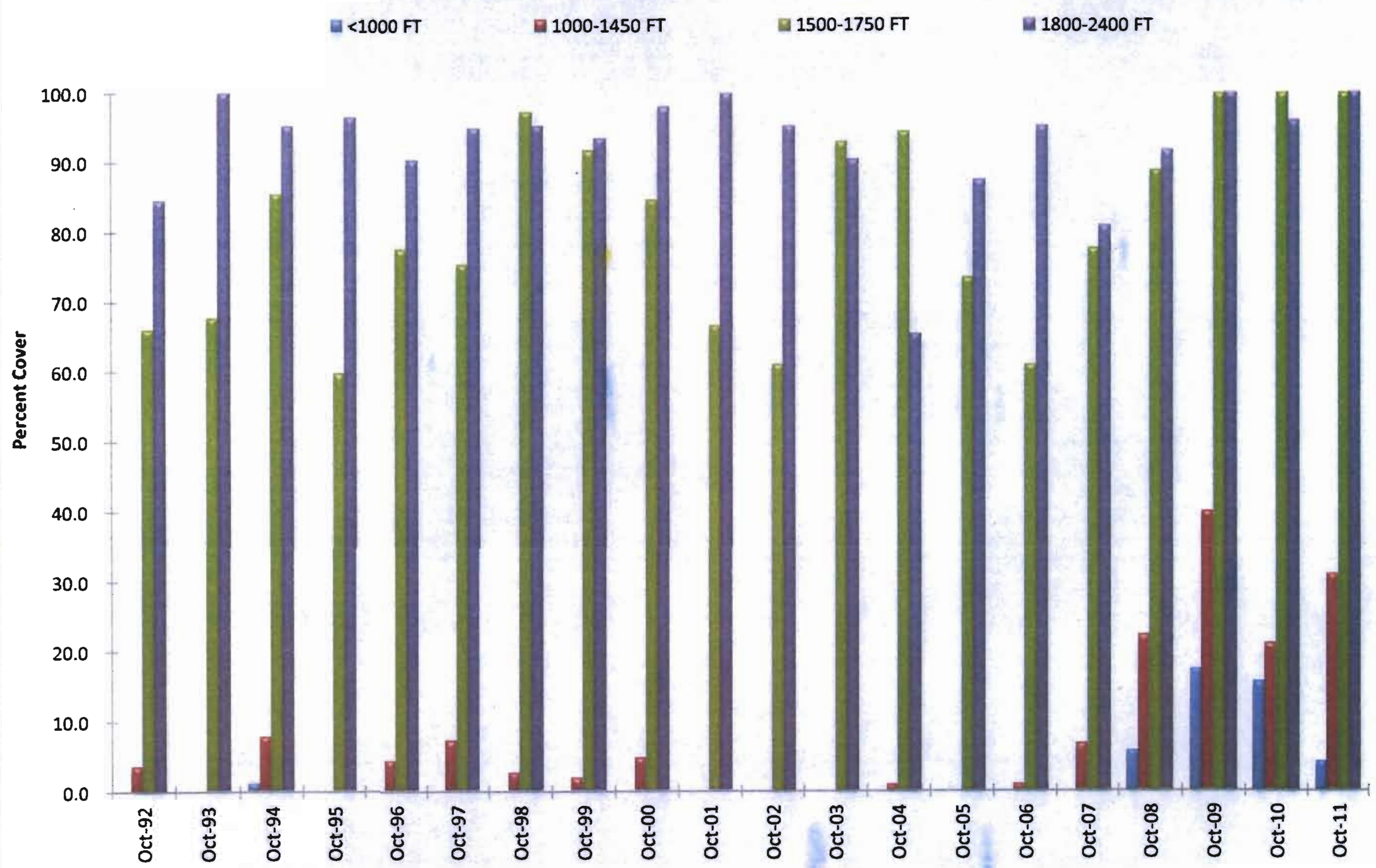

Figure 13. Percent coverage of Turtle grass, *Thalassia testudinum*, along Transect 2 Cutler embayment, October 1992 - October 2011.

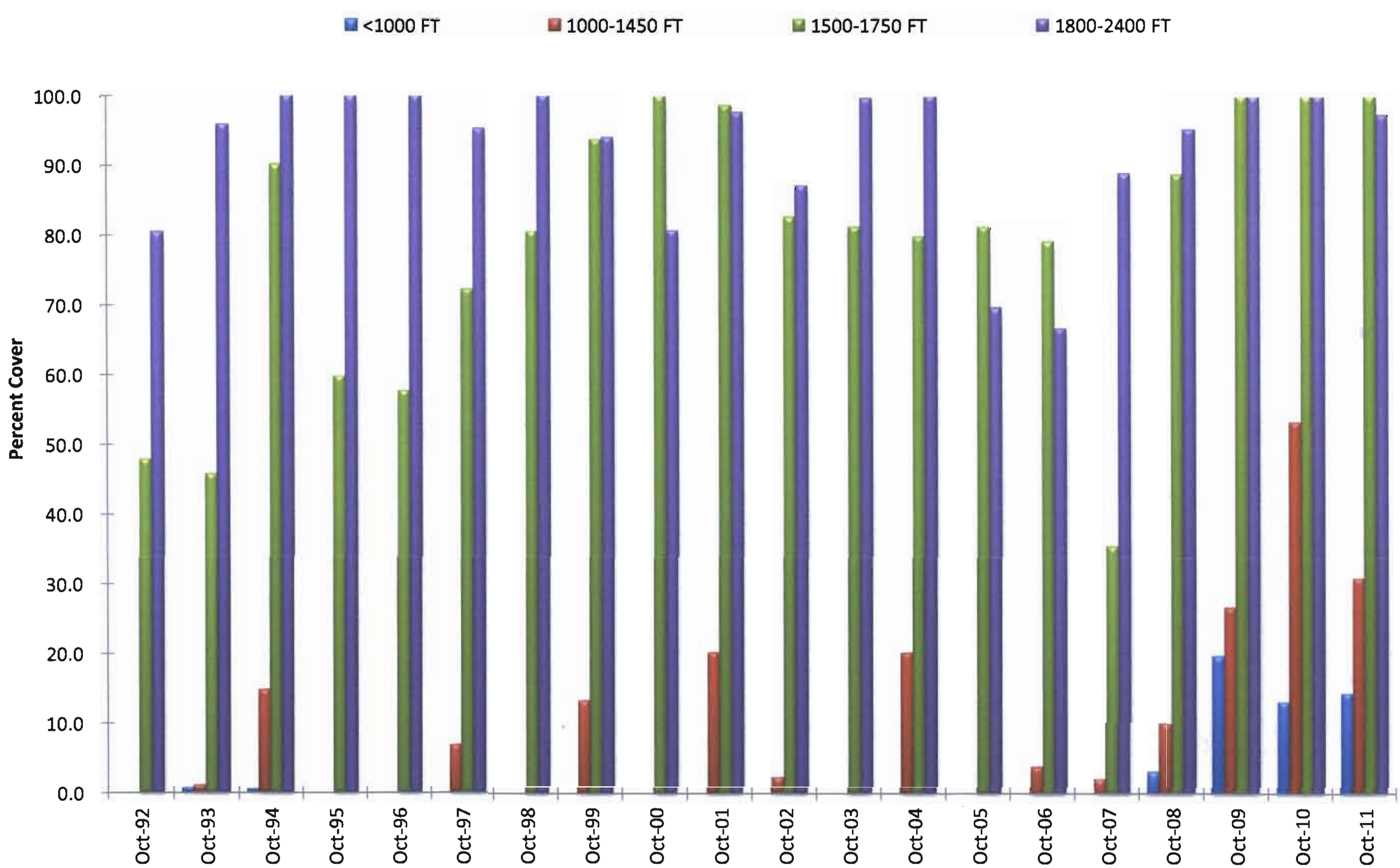

Figure 14. Percent coverage of Turtle grass, *Thalassia testudinum*, along Transect 3 Cutler embayment, October 1992 - October 2011.

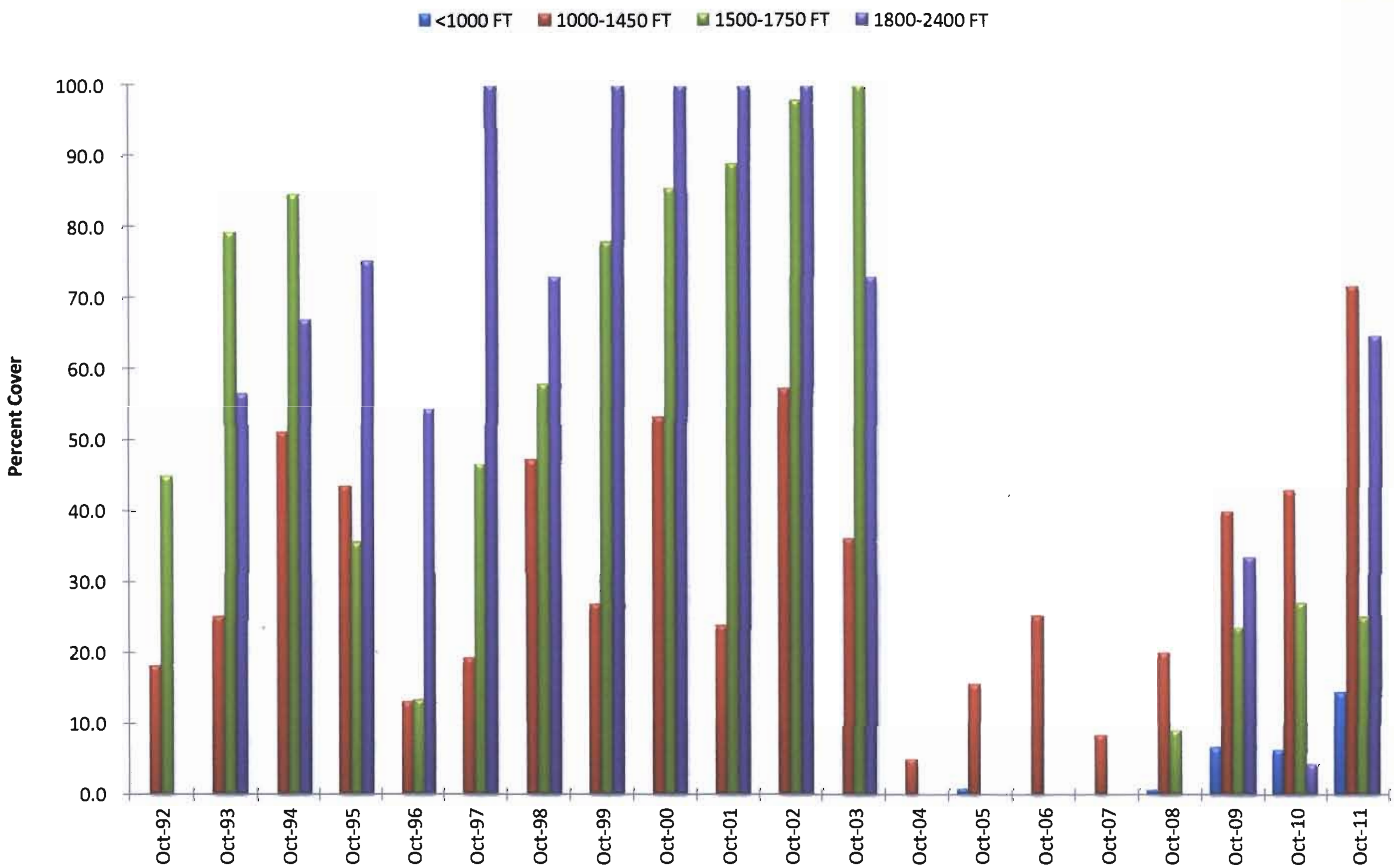

Figure 15. Percent coverage of Turtle grass, *Thalassia testudinum*, along Transect 4 Cutler embayment, October 1992 - October 2011.

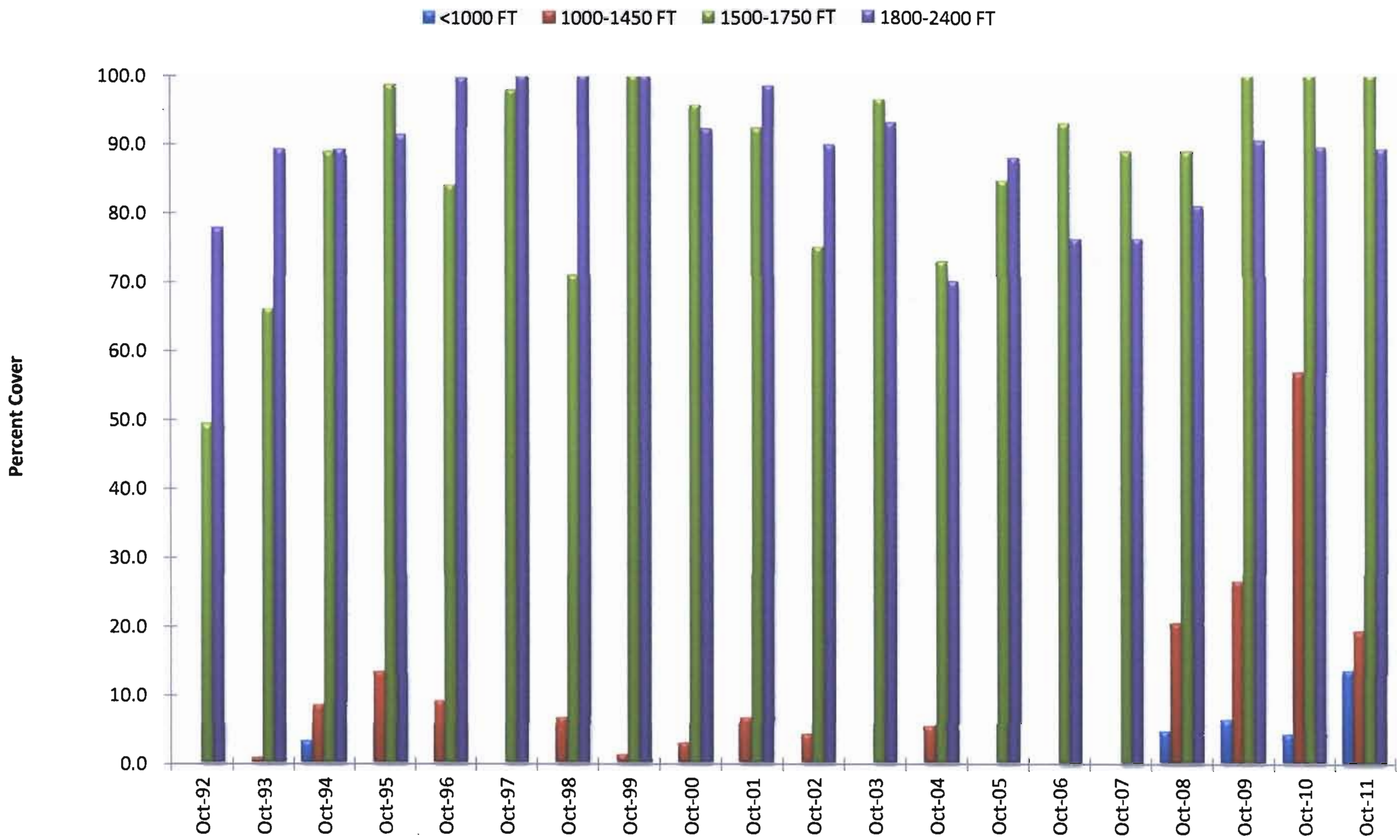

Figure 16. Percent coverage of Turtle grass, *Thalassia testudinum*, along Transect 5 Cutler embayment, October 1992 - October 2011.

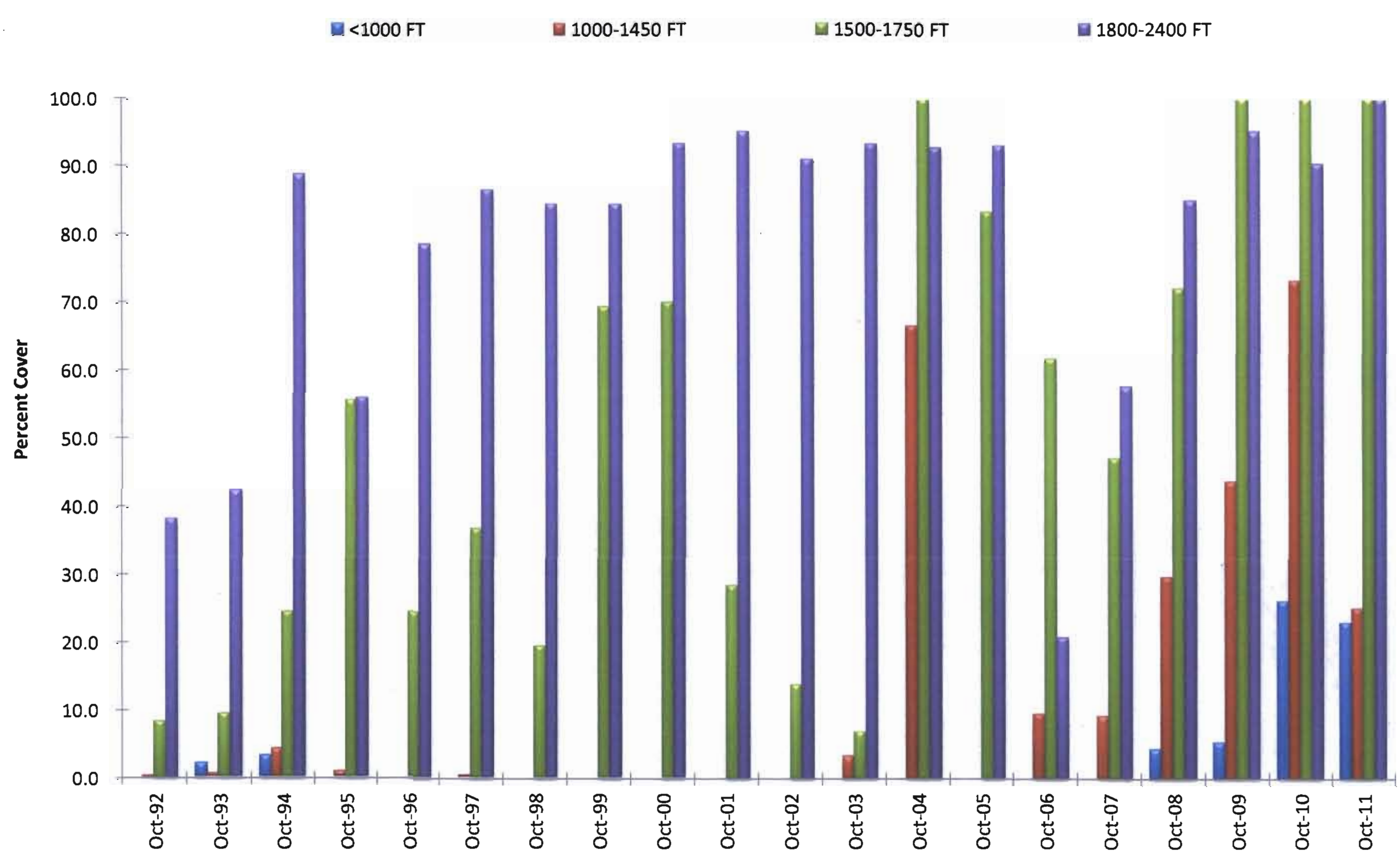

Figure 17. Percent coverage of Turtle grass, *Thalassia testudinum*, along Transect 6 Cutler embayment, October 1992 - October 2011.